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CHEMICAL SECTION.
ELECTRICAL SECTION.

Joint Meeting, May 26, 1896.

MR. CLAYTON W. PIKE in the chair.

THE TRANSFORMATION OF THE ENERGY OF CARBON INTO OTHER AVAILABLE FORMS.

BY C. J. REED.

The energy of carbon, and hydrocarbons such as coal, is probably the most stable of all the forms of energy with which we are directly supplied by nature. It is the stability of this energy that has preserved it through countless ages and geological changes. It is this same stability that renders it also unavailable to man until it is brought by transformation into a more tractable or mobile form.

There are five general methods or processes known at present for converting this form of energy into the numerous forms that are directly available to man. They are:

(1) The thermal method.
(2) The thermo-dynamic method.
(3) The thermo-electric method.
(4) The thermo-magnetic method.
(5) The thermo-chemical method.

The simplest is the thermal method, in which, by simple combustion, the energy is converted directly into heat and light, and utilized for warming and illuminating.

The thermo-dynamic method consists in liberating the energy as heat by combustion, and subsequently converting the heat, through the agency of a heat-engine, into kinetic energy.

The thermo-electric method consists in liberating the energy as heat by combustion, and subsequently converting the heat into electrical energy through the agency of a thermo-electric junction.

The thermo-magnetic method consists in first liberating the energy as heat, and subsequently employing the heat to alter the intensity of a magnetic field, producing either mechanical motion or an electric current.

The thermo-chemical method embraces two varieties, each of which consists of two distinct steps or operations. One of these varieties consists in liberating the energy as heat, and subsequently causing it to be absorbed as chemical energy by a secondary substance in an endothermic reaction. The other consists in transferring the molecular energy, without transformation, from the molecules of carbon or coal to the molecules of a secondary substance, where it is less stable and consequently more available. This transfer has been accomplished only at high temperatures and, therefore, it requires the expenditure of some energy in the form of heat.

The second step which follows the thermo-chemical process consists in transforming the energy of the secondary substance into electrical energy through the agency of a galvanic cell.

It will be seen that all these known methods are thermal methods to a greater or less extent; that is, they all require the whole or a portion of the energy concerned to be transformed into heat in the process of becoming available.

Pure carbon manifests no affinity for any known substance at low temperatures. It may be made to combine with oxygen directly only at temperatures above 250° C. Indirectly, and by expending upon it the energy of powerful oxidizing agents, or the energy of an electric current, it may be slowly oxidized at low temperatures. But all attempts, without exception, to obtain energy from carbon at low temperatures have totally failed.

Numerous compounds of carbon, such as carbon monoxide and various hydrocarbons, are easily oxidized at low temperatures by powerful oxidizing agents; but such reactions have not evolved available energy.

The best method of transforming the chemical energy of carbon or coal depends largely upon the form in which the energy is desired. Where, for instance, the desired form of energy is unconfined heat of moderate degree or intensity, the thermal method, by combustion in air at a high temperature, is both practically and theoretically perfect in efficiency.

Where the energy is desired in some other higher form than heat of moderate intensity, it may be obtained from carbon only at a great loss, determined in each case by particular conditions.

If heat of high intensity is the desired form, it may also be obtained directly by thermal combustion, but only at a greatly reduced efficiency, since by this method all heat evolved, which is not up to the proper intensity, is rejected and unavailable.

With the thermo-dynamic method, in which the heat is transformed into mechanical motion or kinetic energy by the alterations in volume of a working substance, the maximum efficiency is limited by the second law of thermodynamics, to the difference between the initial and final temperatures divided by the initial temperature. By this method an efficiency of from 3 to 10 per cent. is generally

obtained. The method is so generally understood that it needs no further mention here.

In the thermo-electric method the efficiency of transformation, in addition to being limited by the second law of thermo-dynamics, is limited also to the difference between the Peltier effects at the hot and cold junctions divided by the Peltier effect at the hot junction, an expression which is in the same form as that for the maximum efficiency of a thermo-dynamic process.

Comparing these two methods, we have in the thermo-dynamic transformation

$$E = \frac{T - T'}{T},$$

in which T and T' represent respectively the absolute temperatures at which heat is received and rejected in a heat engine, E being the maximum efficiency.

In the thermo-electric transformation, we have, in addition to the above limitation, the further limitation

$$E = \frac{P - P'}{P},$$

in which E is the maximum efficiency, and P and P' represent respectively the Peltier effects at the hot and cold junctions of a thermo-electric battery. A thermo-electric circuit may be so chosen that the Peltier effect at the cold junction is zero, though this is not generally practicable. In that case the maximum efficiency would not be limited by this law to less than

$$\frac{P}{P},$$

or 100 per cent.

Unfortunately there are other and more important limitations to this method than the theoretical ones. These are of so serious a nature that the thermo-electric method has not yet equaled, nor even remotely approached in efficiency, the thermo-dynamic method.

Perhaps the greatest drawback to the thermo-electric method of transformation is the fact that there is no known substance that fulfils the requirements of a perfect working

substance, even to a very small extent. A perfect thermo-electric substance must be a perfect conductor of electricity and a perfect non-conductor of heat. But we find in nature that all substances are either very poor conductors of electricity, or else very good conductors of heat. The result of this and other limitations is that no thermo-electric couple has yet been produced which can transform more than a small fraction of 1 per cent. of the heat applied to it into electrical energy.

The principal difficulties of this method may be illustrated by reference to *Fig. 1*, in which *C* represents the cold junctions, and *H* the hot junctions of any thermo-electric battery. All heat that passes by conduction from the hot to the cold junction is necessarily wasted. Hence, the substances should be the poorest conductors of heat. The internal resistance of the battery will be the sum of the

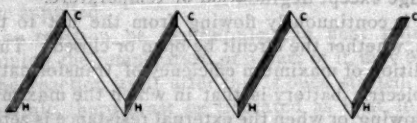

FIG. 1.

resistances of all the bars, *HC*, placed in series. Hence, the substances employed should be the best possible conductors of electricity. But all good conductors of electricity are also good conductors of heat. It is, therefore, impossible to gain any great advantage by choosing a substance with reference either to its thermal or to its electric conductivity; because any advantage that may be gained through increased electric conductivity will generally be counterbalanced by the loss through increased thermal conductivity.

For the same reason it is useless to attempt, with any given substance, to reduce the electrical resistance of the thermo-electric battery by increasing the cross-section of the conductors. Any such decrease in resistance will be counterbalanced by a proportionate increase in the loss through conduction of heat.

Again, we cannot gain any advantage in attempting to

reduce the heat conduction by increasing the distance between *H* and *C*, since this would proportionately increase the internal resistance. Therefore, the efficiency evidently cannot be materially increased by altering the form or dimensions of the elements composing the battery.

The thermo-electromotive force between *C* and *H*, with every known couple, is very small, ranging from $\frac{1}{1000}$ to $\frac{1}{1000000}$ volt for every degree of difference in temperature between *H* and *C*, and is proportional to this difference. But here, again, increasing the temperature of the hot junction, or diminishing the temperature of the cold junction, while it does increase the E.M.F., can result in no improvement in efficiency, since increasing the difference in temperature between the junctions increases, in the same ratio, the rate at which heat will pass by conduction from the hot to the cold junction, where it is rejected without undergoing any change except degradation of temperature.

Heat is continuously flowing from the hot to the cold junction, whether the circuit be open or closed. Therefore, the condition of maximum efficiency of transformation in a thermo-electric battery is that in which the maximum current is flowing, or when the external resistance is zero. This must mean that we can attain maximum efficiency of transformation only when the battery is short-circuited and the current is entirely used in heating the battery itself, the same as though there were no transformation.

In view of these facts, it seems to me that there is little hope for any radical improvement in this method of transformation. Nevertheless, we read, from time to time, accounts of improved thermo-electric batteries (about to be perfected) that are to have a greater efficiency than any other method of transformation.

In the thermo-magnetic method of transformation the energy is first liberated as heat, and the heat used to vary the intensity of magnetization in a magnetic body, with the production of either mechanical motion or an electric current. This method was discovered by Thomson and Houston in 1879, and was communicated to the Franklin Institute at that time; but the results obtained by this method, up

to the present time, are commercially insignificant. As the process depends entirely upon the absorption and rejection of external heat, it is evidently limited by the second law of thermo-dynamics. No attempt has yet been made to apply this method in practice.

The thermo-chemical method of transformation is the only known method by which even a part of the energy of fuel may be brought into an available form without a primal degradation into heat. In this process, energy may be *transferred*, without transformation, directly from the molecules of fuel to the molecules of a secondary substance in which it is less stable.

In carrying out this process it is necessary to develop as heat only so much energy as may be required to maintain the substances involved in the operation at the temperature at which the transfer takes place, unless the reaction is endothermic, in which case additional heat for absorption must be supplied.

If the reaction be exothermic, the heat required for maintaining the temperature, or a part of it, may be derived from the reaction itself after this is once started. If it be endothermic, there must be liberated as heat, in addition to the amount necessary to maintain the proper temperature, an amount equal to that absorbed in the reaction. In this case, a part of the transferred energy passes through the form of heat.

The general method of carrying out the thermo-chemical process is to heat the fuel in a closed chamber to a high temperature in contact with a chemical reagent capable of acting upon the fuel in such a manner as to absorb the energy. The only reagents heretofore employed for this purpose are oxides, and generally metallic oxides, which, in the reaction, become reduced to the metallic state by oxidizing the fuel.

The difference between the formation heat of the oxide employed and that of the oxide formed represents an amount of energy which must necessarily be developed in the form of heat, otherwise the reaction could not occur. If the formation heat of the oxide employed be greater than

that of the oxide formed, the difference is negative, and must be supplied in the form of heat absorbed from an external source. If it be less, the difference between the two is evolved as heat of combustion.

We find, therefore, two limitations to the efficiency of the thermo-chemical process: (1) The loss of the heat necessary to raise the materials to the temperature at which reaction takes place, and to maintain them at that tempera-

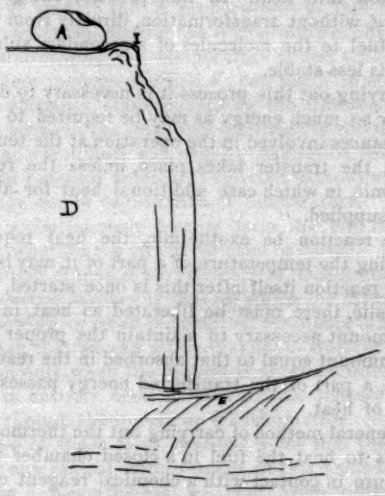

FIG. 2.

ture. (2) The heat necessarily evolved, and which is the equivalent of the difference between the formation heat of the reagent and that of the oxidation product. In cases where this latter heat is evolved by the reaction (that is, where the reaction is exothermic), it may generally be employed to help maintain the temperature. Where it is absorbed by the reaction (reaction endothermic), it must be obtained from without by the combustion of an additional amount of fuel. The result is that, in general, only exother-

mic reactions are easily and economically performed. It follows, also, that the more exothermic a reaction is, the more easily it will be maintained after starting. The more nearly athermal a reaction is, the greater will be the possible efficiency of the transfer from one substance to another, especially in cases where the reaction takes place at a low temperature.

In order to illustrate more clearly the meaning of the above statements, I have arranged a comparison to represent graphically the analogy between chemical energy or molecular potential energy, and ordinary molar potential energy, or the potential energy of elevated masses of matter. I may add that the two are strictly comparable, being not merely similar, but identical.

In *Fig. 2* is represented an elevated mass of rock, *A*, lying on the edge of a plateau on the table-land, *D*. At *I* is an obstruction which prevents *A* from rolling over the precipice into the ravine at *E*. In its elevated position, *A* contains a certain quantity of potential energy, due to its elevation above, and the possibility of its descending to, *E*; or, in other words, due to a certain quantity of separation that has been effected between *A* and the center of the earth.

This energy is in a very stable and unavailable condition. It is held by the obstruction, *I*, which prevents *A* from undergoing any change. This energy we may compare to the energy of separation which exists between a molecule of free oxygen and one of free carbon. The separation of an atom of carbon from two atoms of oxygen, or the reaction

$$CO_2 = C + O_2$$

requires as definite a quantity of energy as does the separation of a pound of rock to a distance 100 feet farther from the earth's center. The only difference between the two cases is that one is a molar, the other a molecular separation. In the one case there is a separation of visible masses, in the other a separation of invisible molecules. In either case, the potential energy acquired is equal to the work done in effecting the separation.

The molecular separation in 1 pound of free carbon is equal to the molar separation of raising 1 ton to a height of 1 mile. This comparison gives a very fair idea of the vast amount of separation or potential energy there is in a pound of carbon. A pound of hydrogen in the ordinary gaseous state contains about four times this amount.

A pound of matter falling without obstruction from an infinite distance to the earth's surface, would acquire a velocity of 7 miles per second, and would strike with an energy of 10,600 foot-tons. But the molecular energy of a pound of hydrogen gas, which is liberated in combining with oxygen, is 23,600 foot-tons. In other words, the chemical energy of hydrogen gas, if applied to its own mass to give it an upward velocity, is two and one-quarter times what would be necessary to project it to an infinite distance whence it could never return.

Returning to our mass of matter, *A*, *Fig. 2*, we find that the only way we can get the energy of this body into an available form is to allow it to descend to *E*. To accomplish this, we must apply some external energy to it, either to remove the obstruction or to raise the body, *A*, high enough to allow it to roll over the obstruction. Its energy of position will then be rapidly transformed into kinetic energy, which will, in turn, after reaching *E*, be transformed into heat. After the obstruction has been overcome, and the mass has begun to descend, its progress cannot be arrested, except by the application of more energy or by some other obstruction.

Similarly, the energy of carbon is held back by a molecular obstruction that prevents it from undergoing a chemical change, or a fall of molecular potential, until sufficient external energy has been applied to overcome the obstruction. A mass of carbon may be allowed to stand in contact with atmospheric oxygen, or even pure oxygen, for ages, and not a single atom will oxidize, though the affinity of the carbon for the oxygen atom is enormous. After the separation of carbon from oxygen has once been effected, the carbon atoms unite with one another, and their mutual attraction, though small, constitutes an insuperable obstruc-

tion to the union with oxygen. This obstruction may be removed, however, by the application of a small amount of external energy in the form of heat, which breaks up the carbon and oxygen molecules and allows the atoms to exercise their affinities for each other. This is well illustrated in the kindling of a fire by applying a lighted match to a shaving. After this reaction has begun it proceeds rapidly, as in the case of our falling elevated body, until all the energy represented by the reaction is converted into heat, and the temperature rises to a point limited only by the specific heat of the products of combustion and the conditions of radiation.

The great drawback to all thermal methods of transformation is the difficulty of modifying this process of combustion, after it has once started, in such a manner as to prevent the degradation of all the energy into heat, and to cause a considerable portion of it to be changed directly into available forms.

In *Fig. 3* is shown, in connection with our elevated body, a wheel and axle, *C*, to which it is desired to apply some of the energy of *A*.

This may be done in a simple manner by allowing *A* to descend and strike *G*, the short end of a lever pivoted at *H*, on the longer end of which, at *F*, is a small mass of stones. The stones are projected upward with a velocity greater than that acquired by the falling body, and some of them drop into the scale-pan, *C*, attached to the rope which operates the wheel and axle. The weight of these stones causes the pan to descend and the axle to revolve, again converting potential into kinetic energy, which is now available.

This method of transforming the potential energy of *A* into the kinetic energy of the wheel and axle is obviously very inefficient, and seems like letting down energy for the sake of raising it up again. It is, however, not so inefficient as the thermo-dynamic method of converting energy of coal into available forms, as generally practised and illustrated in the ordinary steam engine.

Absurd as the arrangement shown in *Fig. 3* seems, it could undoubtedly be made, by a suitable refinement of the

mechanism, to operate with an efficiency of more than 90 per cent., which is incomparably greater than anything ever yet attained by any method of transforming energy of fuel into kinetic energy.

The reason for this, I think, is obvious. It is this; that in the transformation of molar potential energy into other

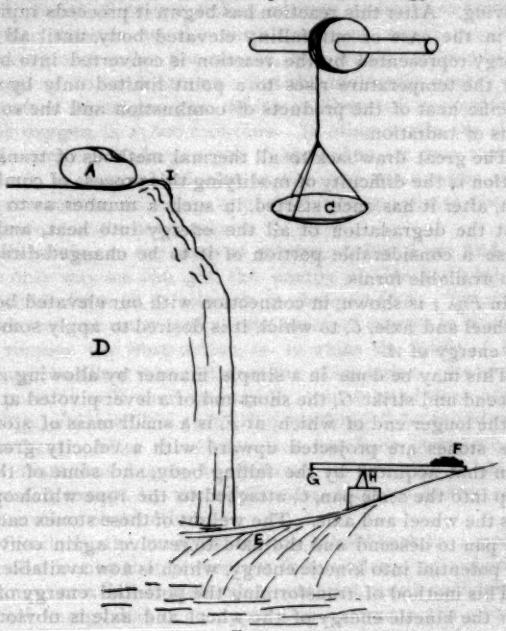

FIG. 3.

forms, there is no necessity for its primal degradation into heat; whereas, in the case of the molecular potential energy of all substances commonly called fuel, there is no known method of transformation except by a thermal or partially thermal process.

It is my purpose to show that, by a proper application of

the thermo-chemical method, followed by the galvanic process, it is possible to transform the molecular energy of fuel with an efficiency comparable to that of molar transformation, and to do so without resorting to any extreme or abnormal conditions of temperature.

To follow out the comparison instituted above, this method may be illustrated in *Fig. 4*.

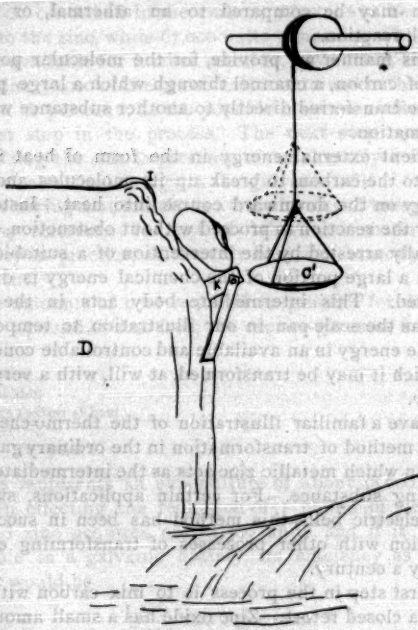

FIG. 4.

We first apply a small amount of energy to the scale-pan to bring it down to *C'*. An artificial obstruction is also placed at *K*, before removing *I*, to arrest the motion of the falling body and divert it into the scale-pan. A large part of the potential energy of *A* is thereby transferred directly

to the scale-pan, instead of being first transformed into kinetic energy, which would still be unavailable. The letting down of the body from its original position to the point *K* may be compared to a chemical reaction in which carbon undergoes combination in the formation of an unstable or combustible carbon compound, without giving up all its energy. The transfer of the mass from *K* to the scale-pan may be compared to an athermal, or nearly athermal, reaction.

In this manner we provide, for the molecular potential energy of carbon, a channel through which a large part of it may be transferred directly to another substance without transformation.

Sufficient external energy in the form of heat is first applied to the carbon, to break up its molecules and start its energy on the downward course into heat. Instead of allowing the reaction to proceed without obstruction, it may be partially arrested by the intervention of a suitable body to which a large portion of the chemical energy is directly transferred. This intermediate body acts in the same manner as the scale-pan in our illustration, to temporarily retain the energy in an available and controllable condition, from which it may be transformed, at will, with a very high efficiency.

We have a familiar illustration of the thermo-chemical-galvanic method of transformation in the ordinary galvanic battery, in which metallic zinc acts as the intermediate body or working substance. For certain applications, such as ringing electric bells, this method has been in successful competition with other processes of transforming energy for nearly a century.

The first step in the process is to mix carbon with zinc oxide in a closed retort. Zinc oxide has a small amount of available molecular potential energy, but much less than metallic zinc. We apply to the retort, from an external source, sufficient heat to raise the temperature of the mass to about 1,100° C. At this temperature the carbon is capable of taking oxygen from the zinc oxide, and thereby undergoing partial combustion, a part of its energy being transferred directly to the zinc.

The following equation represents the change:

$$ZnO + C = Zn + CO$$

The products of this reaction, Zn and CO, contain respectively 85,000 and 67,000 units of molecular energy, the original C containing 97,000. There must have been absorbed, therefore, from without, 55,000 units of heat. Of the 97,000 contained in the carbon, 30,000 have been transferred to the zinc, while 67,000 units remaining with the CO are not available for further reaction. We have, therefore, in the zinc, 30,000 of the 97,000 units contained in the carbon, or about 31 per cent., as the possible maximum efficiency of the first step in the process. The next step consists in re-oxidizing the zinc in presence of an electrolyte with evolution of electrical energy in the galvanic cell.

Considering zinc merely as a transformer of energy, without any reference to cost of labor and materials, its efficiency in practice, at the very best, can scarcely exceed 2 per cent.

The amounts of coal required in practice for the reduction of 1 pound of zinc from the ore are given as follows:

	Pounds.
Roasting	·34
Reduction	1·25
Firing (external heat)	5·00
Total	6·69

This represents an expenditure of about 48,000 thermal units in effecting the reduction of 1 pound of zinc. The reduced zinc acquires only 1,300 units, and if it were all available in a galvanic battery, its efficiency as a transformer would be

$$\frac{1,300}{48,000} = 2{\cdot}6 \text{ per cent.}$$

But the reduction of zinc to the metallic state is not the only step in the process. The metal must be re-melted, cast, rolled, amalgamated and properly connected in the cell. The mechanical preparation generally entails a loss of 5 per cent. In the final step the zinc is not all utilized. If

the zinc be not well amalgamated, there is generally lost by local action from 50 to 90 per cent. Even if the zinc be well amalgamated, the mercury tends to collect at the lower part of the plate, and the principal action then takes place at the surface of the solution. At this point the plate soon becomes eaten through, and breaks, leaving two pieces of practically worthless scrap zinc, one in the bottom of the cell and the other hanging above the solution. It is safe to say that in actual practice of all kinds, not less than 50 per cent. of the zinc of primary batteries finally deposits its expensive energy in an unavailable scrap heap. Assuming this figure to be roughly correct, we have the net efficiency of zinc as a transformer reduced to 1·3 per cent.

The final step in the transformation is the oxidation of zinc upon closure of the battery circuit. This should take place at a temperature below that at which the solution will attack the zinc on open circuit.

If zinc and atmospheric oxygen were the only substances required in oxidizing the zinc, the only limit to the maximum efficiency of this step in the process would be 100 per cent. But as a matter of fact we cannot oxidize even metallic zinc directly by atmospheric oxygen in such a way as to obtain electrical energy from it. It has little more affinity for oxygen at low temperatures than carbon. Its energy may be transformed into electrical energy only by taking advantage of its affinity for other substances with which it forms "salts," instead of its affinity for oxygen. Such reactions take place in the cold readily and evolve greater energy than could be obtained by direct oxidation. Carbon, unfortunately, has no such affinities, and forms no such compounds as *salts*.

We have for heats of formation in solution:

	Units.
For zinc oxide, $Zn + O = ZnO$	83,000
" zinc sulphate, $Z + O + SO_3 = ZnSO_4$	108,000
" zinc chloride, $Zn + Cl_2 = ZnCl_2$	113,000

Unfortunately, the zinc salts formed as products of these reactions, $ZnSO_4$, $ZnCl_2$, etc., are not the original transforming substance, ZnO, and cannot be again reduced to metallic

zinc without the expenditure of vastly greater amounts of energy than that required to reduce ZnO. So great is the energy required for the reduction of the sulphate, that, if we were actually to carry it out in practice, our efficiency of 1·3 per cent. would have to be again divided by a large number. Heretofore, these products have always been thrown away in preference to reducing them.

Another serious loss in the zinc battery is that these by-products, which must be rejected, carry with them into the scrap heap, not atmospheric oxygen, but the (SO_4), Cl, or other expensive materials used in oxidizing the zinc.

The process, when operated with zinc as a transforming substance, is, therefore, not a complete or cyclic process, since the transforming substance never passes through the same condition twice. It is really more a process of transforming matter than one of transforming energy.

Any process of transforming the energy of fuel is not complete and cannot successfully compete with thermo-dynamic processes on a large scale, if it necessitates the continuous consumption of any material other than the fuel itself and air, or if it finally rejects as by-products any materials besides the products of combustion.

I have taken zinc as an illustration of a working substance through which the energy of fuel may be transformed by the thermo-chemical method, not because it is a suitable substance, but because of our familiarity with it.

While zinc may be profitably employed as a transformer in this manner for particular cases, such as gas lighting, bell-ringing, etc., where comparatively insignificant quantities of energy are to be transformed, it cannot compete in efficiency on a large scale with thermo-dynamic methods.

The commercial failure of the galvanic battery to compete with steam is not, however, due to any inherent defect in the thermo-chemical-galvanic method of transformation, but entirely to the fact that zinc, as pointed out above, is not a suitable working substance to use as a transformer.

The objections to the behavior of zinc as a transforming substance teach us what is to be desired and what is to be avoided in seeking an ideal transforming substance. They

indicate, also, that there is little hope for improvement in the method, so long as we employ zinc or any similar metal as a transformer.

I believe we may go even a step further and say that there can be no radical improvement in this method so long as the transforming substance constitutes at the same time one of the electrodes of the battery.

A galvanic battery, like any other apparatus, in order to be of great practical applicability, should be capable of maintaining its mechanical integrity. If we were to succeed even in substituting carbon for zinc in the galvanic battery of ordinary form, I believe it would result in no material saving; for carbon in a good mechanical form is as expensive as zinc in the same form. The most serious defect in the galvanic battery, as a mechanism for transforming energy, lies in the fact that it can operate only by destroying its own mechanical integrity, to replace which is much more expensive than the mere materials of which it is built up.

What would be thought of the commercial utility of a steam engine that derived all its energy from the oxidation of its own piston-rod; or of a steam boiler that could utilize no energy except what was derived from the oxidation of its tubes; or of a dynamo that could supply no electric current except what might be derived from the burning of its brushes or commutator?

Yet this is exactly the sort of mechanism we have in all galvanic batteries. The only energy that can possibly be evolved is that which comes from the mechanical destruction of the battery itself. This seems to me a much more serious difficulty than any difficulty arising from inefficiency in the actual transformation.

Nevertheless, the galvanic cell is the only known instrument by which chemical may be directly transformed into electrical energy, and there is no theoretical limitation to its possible efficiency.

The ideal cell should consist of two indestructible, or reasonably permanent, conducting solids, in contact with a liquid electrolyte. The electrolyte should consist of two

solutions, separated by a porous partition, through which one of the solutions flows. Each of the two solutions should contain a chemical reagent capable of combining with the other, on contact of the solutions, in an exothermic reaction.

The working or transforming substance should be capable of acting upon carbon at as low a temperature as possible, without evolution or absorption of much energy, and with formation of an unstable carbon compound easily oxidized to CO_2. The working substance should also be capable of combining with atmospheric oxygen at as low a temperature as possible, without the evolution or absorption of much energy, and with formation of an unstable oxygen compound. These two compounds of the transforming substance, one of carbon and one of oxygen, should constitute the active chemical reagents of the cell, and should be capable of uniting on contact in the cold electrolyte, with formation of CO_2 and precipitation of the transforming substance in its original free state. Arrangements should be such that the exhausted electrolyte may continuously flow out of the cell and regenerated material flow in.

Such a set of reactions would be represented by the following equations, in which T represents one combining equivalent of the transforming substance, C, an equivalent of carbon, and O, an equivalent of atmospheric oxygen:

$$T + O = TO. \quad (1)$$

$$C + T = CT. \quad (2)$$

$$2TO + CT = CO_2 + 3T. \quad (3)$$

In equation (1), TO represents the secondary reagent produced by the action of T upon atmospheric oxygen, and CT, in equation (2), represents that produced by the action of T upon carbon. All three of these reactions should be exothermic, and the first two as nearly athermal as possible.

The reagents TO and CT are the active materials which are brought in contact in the battery. Equation (3) represents the reaction that takes place in the discharge of the battery, CO_2 and T being the products of discharge. CO_2, identical with the product of combustion of carbon in air, is

rejected, while T is the regenerated working substance, and may be used an indefinite number of times.

It will be seen that the only substances used in these reactions are carbon, atmospheric oxygen and the transforming substance. The substances produced are carbon dioxide and the regenerated transforming substance.

The question naturally arising at this point is, whether there can be found in nature a transforming substance answering these ideal requirements.

In answer to this question, I find there are a number of substances, all answering the requirements to some extent, some to a very great extent. A surprising fact is that these substances, instead of being highly electro-positive metals,

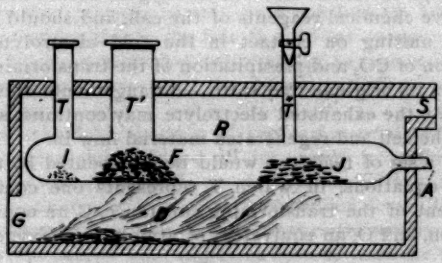

FIG. 5.

like zinc, iron, magnesium, etc., are not metals at all, being, without exception, non-metallic substances. By non-metallic, I mean that they do not, at any stage of the cycle of chemical changes through which they pass, come into a metallic state. In most cases the best results are obtained, not by following exactly the formula laid down in equations (1), (2) and (3) above, but by indirectly bringing about an equivalent series of reactions.

To illustrate this cyclic method of thermo-chemical transformation, we shall take as our transformer the two substances, sulphur and water; as fuel, carbon, and as oxidizing agent, atmospheric oxygen.

The first step in the process is the combustion of sulphur

in the air, with production of sulphur dioxide, SO_2, and the evolution of 71,000 units of heat, as represented in equation (4).

$$S + O_2 = SO_2 + 71{,}000 \qquad (4)$$

The SO_2 formed by this reaction is passed through water, which absorbs it and forms the oxidizing electrolytic solution. Some sulphuric acid may be added to increase the conductivity.

The heat developed by the combustion of the sulphur is applied to a retort, *R*, shown in *Fig. 5*. Carbon is admitted to this retort at *F*, through the tube *T'*; sulphur is admitted at *I* through the tube *T*; and water is allowed to drop upon a pile of broken crockery or stones at *J*. The sulphur is burned at *D* with air supplied through the opening *G*. The SO_2 passes out at *S*. The heat from the sulphur burning at *D* heats the carbon, *F*, to a dull-red heat. The sulphur, *I*, is vaporized, and, passing over the heated carbon, forms carbon disulphide, according to the following equation:

$$\left\{\begin{matrix}97{,}000\\ C\end{matrix}\right\} + \left\{\begin{matrix}142{,}000\\ S_2\end{matrix}\right\} + \left\{\begin{matrix}19{,}000\\ \text{Heat}\end{matrix}\right\} = \left\{\begin{matrix}258{,}000\\ CS_2\end{matrix}\right\}$$

The carbon contains 97,000 and the S_2 142,000 units of molecular potential energy referred to oxygen, and the CS_2 formed contains 258,000. Hence there must be absorbed in this reaction 19,000 units of external heat.

The CS_2 vapor comes next in contact with the steam and hot bricks at *J*, where double decomposition occurs with the absorption of 14,000 units of external heat and the formation of hydric sulphide and carbon dioxide, represented as follows:

$$\left\{\begin{matrix}258{,}000\\ CS_2\end{matrix}\right\} + \left\{\begin{matrix}0\\ 2H_2O\end{matrix}\right\} + \left\{\begin{matrix}14{,}000\\ \text{Heat}\end{matrix}\right\} =$$

$$= \left\{\begin{matrix}272{,}000\\ 2H_2S\end{matrix}\right\} + \left\{\begin{matrix}0\\ CO_2\end{matrix}\right\}$$

The final products, H_2S and CO_2, pass out at *A*. The H_2S may be absorbed in water, which becomes the reducing

electrolytic solution, or it may be used in the gaseous state.

We have now expended the energy of

	Units.
3 equivalents of S = 3 × 71,000	= 213,000
1 equivalent of C	= 97,000
Total	= 310,000
We have transferred into H_2S	= 272,000
Lost as residual furnace heat	= 38,000

The next operation is to bring the SO_2 and H_2S together in a manner such that electrical energy will be evolved, and the transforming substances, sulphur and water, will be regenerated.

In the well-known reaction between SO_2 and H_2S in the gaseous state, we have a most beautiful example of spontaneous combustion at low temperatures. It is represented by the following equation:

$$\left\{\begin{matrix}270{,}000\\2H_2S\end{matrix}\right\} + \left\{\begin{matrix}0\\SO_2\end{matrix}\right\} = \left\{\begin{matrix}0\\2H_2O\end{matrix}\right\} + \left\{\begin{matrix}213{,}000\\3S\end{matrix}\right\} + \left\{\begin{matrix}59{,}000\\\text{Heat or Electrical Energy.}\end{matrix}\right\}$$

Our final products are the original 2 molecules of water and 3 molecules of sulphur, which were used as the transforming substances.

The sole function of these substances has been to receive 59,000 units of the 97,000 units of energy contained in an atom of carbon, and deliver it, in a reaction that takes place at a low temperature, even in cold solution, either in the form of heat, or of electrical energy without heat.

An apparatus in which this final reaction may take place is shown in *Figs. 6* and *7*. In *Fig. 6* the carbon electrodes, *C*, are in contact with one solution, either the SO_2 or the H_2S, while the carbon electrodes, *C'*, are in contact with the other solution. The two solutions are separated by the porous cups, *E*. The solution within the cups should be at a higher level than that outside.

The SO_2 and H_2S may be delivered in the gaseous state under pressure to the apparatus shown in *Fig. 7*. One gas is delivered through the tubes, *P*, to the interior of the hollow carbon electrodes, *C*, and the other through the tubes, *P'*, to the hollow carbon electrodes, *C'*, both being immersed in dilute sulphuric acid. The electric circuit is completed by the wires, *W* and *W'*. The pressure should be sufficient to force the gases through the pores of the carbon electrodes into the electrolyte in which they dissolve. The regenerated

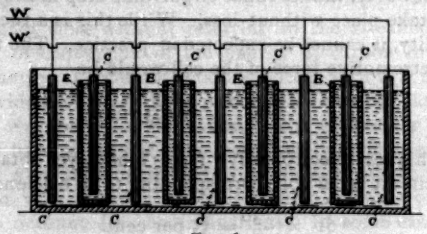

FIG. 6.

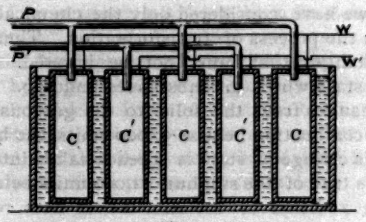

FIG. 7.

sulphur is precipitated as a white powder, and may be separated by filtration or settling.

The balance sheet of our energy now stands:

1 atom of carbon expended	97,000	
3 atoms of sulphur expended	213,000	
3 atoms of sulphur regenerated		213,000
Heat lost in furnace		38,000
Transformed into electrical energy		59,000
	310,000	310,000

The 3 atoms of sulphur regenerated are exactly equal to the 3 atoms used, and hence they may be eliminated, leaving, as the net transaction, 1 atom of carbon expended and 59,000 units transformed into electrical energy, or a maximum efficiency,

$$E = \frac{59,000}{97,000} = 61 \text{ per cent.}$$

The actual attainment of 61 per cent. efficiency would require, however, that the final or galvanic step in the process should take place without loss. While this is a theoretical possibility, it cannot be expected in practice. The theoretical electromotive force of the cell would be

$$\frac{59,000}{4 \times 23,260} = 0{\cdot}63 \text{ volt.}$$

The highest electromotive force I have yet obtained on closed circuit is ·36 volt, corresponding to an efficiency of

$$61 \times \frac{{\cdot}36}{{\cdot}63} = 35 \text{ per cent.}$$

So far, we have considered only the chemical reactions involved in the process of transformation. There are also physical changes that must not be ignored. I refer to changes of state which the substances undergo. Carbon in burning changes from the solid to the gaseous state. In stating its combustion heat as 97,000 units, the heat necessary for this change of state is already taken into account. The same is true of the sulphur, 71,000 units being evolved as heat in addition to the amount of heat required to convert the solid sulphur into the gaseous state. The 2 molecules of water, which enter into the reaction in the liquid state, do not supply any molecular energy, and an additional 19,200 units must, therefore, be supplied in the furnace to convert this water into steam. This energy will again be evolved when the H_2S and SO_2 liquefy by solution in water; but it certainly could not be available in the apparatus shown in *Fig. 6*, since the gases are brought into solution before coming into the battery. Whether any of this energy would be available in the apparatus shown in

Fig. 7, I am not prepared to state. This 19,200 units of heat of vaporization might, in practice, be obtained from the 38,000 necessarily dissipated in the furnace, and need not, therefore, necessarily affect the figures given above for efficiency.

While I do not regard this particular process of carrying out the method as being commercially of great importance, I believe it indicates the only direction in which we are likely to attain any great improvement over thermo-dynamic methods.

I cannot close without referring to the so-called direct method of conversion of the energy of carbon into electrical energy. I shall not detain you long with this method, as no evidence has yet been published which indicates that it has ever been accomplished. The claims for such a method have generally been made solely upon the indications of a voltmeter attached to a carbon electrode, in combination with chemical reagents, which, alone, were sufficient to account for the indications. In some cases, also, thermo-electric junctions, in which carbon and a metal were joined by a fused salt, have been mistaken for galvanic batteries.

As for the development of electrical energy by the combustion of hydrogen and certain gaseous hydrocarbons in contact with an electrolyte and platinum-black, it must be remembered that these substances are neither carbon nor original fuel, and that their energy is obtained, by a thermo-chemical process, from the energy of fuel.

The reading of the paper was followed by experiments, which showed the reaction between H_2S and SO_2, under various conditions. In one experiment, a modification of the apparatus, shown in *Fig.* 7, was used, and an electromotive force was obtained, on closed circuit, of ·32 volt.

Several experiments were also performed with an extemporized Jacques battery, all of which showed that the Jacques battery is a thermo-electric, and not a galvanic battery.

It was shown that, at low temperatures, while the caustic alkali contained considerable water, the carbon was positive to the iron; but that at a high temperature, after the alkali had become highly de-hydrated, the carbon was negative to the iron.

The carbon rod was replaced, successively, by rods of brass, copper, German-silver and iron, without appreciably affecting the result, and a current of illuminating gas was passed into the fused alkali in place of the current of air employed by Jacques. The result was unchanged, showing that the action of the current of air was not to produce oxidation, but to cool the upper layer of the alkali.

UTILIZATION OF THE ANTHRACITE CULM HEAPS IN THE PRODUCTION OF POWER.*

By Nelson W. Perry, E.M.

The doctrine of the survival of the fittest has become so universally accepted as to be its own best illustration of its truth.

A process, a type or a theory, can only prevail as it proves its better adaptability to the conditions, than do those with which it competes; but no process or type—and we may also say no theory—can be considered perfect, because conditions are constantly changing, and that which was best yesterday may be supplanted by something better suited to the environment of to-day. Thus the need for invention ever exists, even in the face of supposed perfected conclusions.

In the mad struggle of the present day for supremacy, no one who would be in the race can afford to be without the assistance of the best thought of the times, and it is this want that has made our times the engineering era of the world's history.

* A lecture delivered before the Franklin Institute, March 13, 1896.

If I might suggest a comprehensive definition of the engineer, I would say that he is one who makes two blades of grass grow where but one blade grew before. He is the skilled adapter of the means at hand to the desired end.

In the history of our early gold and silver mining, material was thrown away which produced fortunes for those who came after, and in the history of our coal mining, fuel has been discarded, which in the future is to turn the wheels of industry; and that which actually constituted a drain upon our resources is henceforth to contribute to our wealth.

The most significant indication of the progress of engineering science is the rapidly increasing directions in which hitherto waste products are being turned to account, and it is in one of these directions that I would direct your thoughts to-night.

The most potent factor in the march of civilization, undoubtedly, is the cheapening of our methods of producing power; and, perhaps, second only to this in importance is the improvement in methods of transmitting this power from the point where it can be produced to the best advantage to the point where it can be utilized most advantageously.

While it is true that there are some industries in which the cost of power forms so considerable a factor in the cost of the manufactured article as to be controlling, it is, nevertheless, true, that if we consider the manufacturing industries as a whole, the cost of power amounts to only about 10 per cent. of that of the product; and in many cases, therefore, it is cheaper to bring the power to the raw material than the latter to the former.

Niagara, with its enormous water-power now partly utilized, has already attracted the attention of the whole world, and the promise of cheap power is held as an inducement to outside manufacturers to locate there or in the vicinity. So interesting to the commercial world has been this feat, that, were tumbling waters sentient beings, we might imagine every mountain stream trembling lest its time to wear the yoke should be near at hand. But

vast as is the available power at Niagara, and numberless as are the other possible water-power centers of lesser magnitude, they cannot, even all combined, meet every industrial requirement. Other neglected sources of cheap power have been sought for and found, and these, too, will be utilized.

The coal mines, from the time of their opening, have been throwing away material which this generation is beginning to appreciate as of value, and as the old tailings from the silver mines have been worked over with profit, we are beginning to work over the culm piles from the coal mines and to appreciate their value.

When we bear in mind that every ton of these culm accumulations not only has been paid for by those who have used the more marketable coal from which it was discarded as refuse, but also is occupying real estate which is growing more valuable every day, we see that in these accumulations there is a source of potential energy which, if less inexhaustible than that of Niagara, is still enormous and quite as available.

Since it has not only been paid for, but is a cumberer of the ground, and furthermore has been proved to be a valuable fuel when properly utilized, the question has naturally arisen: how may it be utilized most effectively for the generation of power?

As to the available quantity of this culm, perhaps the most reliable estimate is that given by the commission appointed by the Governor of Pennsylvania to investigate and report on the waste of coal. This commission, at the date of its report, May 20, 1893, consisted of Eckley B. Coxe, Heber S. Thompson and William Griffith, and, during its active existence, had the valuable assistance of P. W. Shaefer and J. A. Price, who were removed by death. The reputation of all of these gentlemen is such as to give any conclusions arrived at by them the full force of authority.

After estimating the proportions of the total coal mined that was wasted on the dumps in a number of the leading collieries, which varied from 19·7 per cent. to 74 per cent., they say: "Taking into consideration that the percentage

of coal now sent to the dirt bank is much less than formerly, and the annual production greatly increased, it perhaps would not be unfair to estimate that, since the commencement of mining, the coal and coal dirt sent to the culm banks has been 35 per cent. of the total production, say, 315,700,000 tons."

Mr. William Griffith, under date of April 20, 1892, contributed an article to the *Colliery Engineer and Metal Miner*, in which he estimated, on a basis of 20 per cent. waste, that the amount of clean coal that went to the culm bank in the Scranton district alone, up to and including the year 1891, was 21,975,444 tons.

The estimated total production of this district for the year 1891 was 6,193,390 tons. The output for 1895 amounted, in round numbers, to about 7,000,000 tons. If 20 per cent. of this goes to the culm bank, there is a stream of energy annually flowing to that repository of 1,400,000 tons.

Emery estimates 14·4 tons of coal per annual horse-power, for 365 days of 20 hours each for simple, high-speed, non-condensing engines.[1]

If we assume that the fuel value of this coal, when recovered, is but 78 per cent. of that of the best freshly mined egg, stove and chestnut, this 14·4 tons becomes 18·5 tons,[2] and the 1,400,000 tons now annually going to the culm heap represent a stream of energy equivalent to 75,672 horse-power. This is nearly equal to the maximum estimated capacity of the great Niagara tunnel. But in addition to this as yet practically unutilized flow of energy, there is that vast amount already stored up in the culm banks during the years previous to 1892, estimated at nearly 22,000,000 tons (see *ante*), which, on the same basis, is equivalent to over 1,100,000 horse-power years—the storage of which, in one sense at least, has already been paid for. This annually increasing flow of energy may not inaptly be called the Falls of Scranton, which, unlike the Falls of Niagara, have

[1] Emery, on "Cost of Steam Power," *Trans. Am. Inst. El. Engineers*, Vol. X.

[2] Wm. McClave, in paper before Anthracite Coal Operators' Association, Philadelphia, Jan. 9, 1895.

not, as they passed by, dissipated their energy, but which, in succeeding years, have stored it up in an available form for utilization at our pleasure.

Some of the industrial establishments at Scranton obtain their culm from their own mines. One of the largest of these is the Lackawanna Iron and Steel Company. This company charges itself a nominal sum of 10 cents per ton for the culm it uses, and it is shoveled into the furnaces just as it comes from the breaker.

The Scranton Illuminating, Heat and Power Company owned a culm pile which was in the way of the Central Railroad of New Jersey. The railroad company was glad to remove the culm, and entered into a contract to supply an equivalent amount as wanted. This they have been doing for years, delivering the culm for nothing at the doors of the electric lighting station.

The Suburban Electric Light Company also owns a culm pile, at the base of which its station is built. Allied interests are engaged in preparing this culm for market. The refuse is carried by a conveyor into the boiler house of the lighting station at small cost.

Parties in and around Scranton have offered me culm, in the bank, in practically unlimited quantities, at from 10 to 15 cents per long ton.

It costs about as much more to properly size it so that it may be said to cost, on board the cars, at the breaker, from 25 to 30 cents per ton.

When culm is spoken of in the culm bank it refers to all of the material, both large and small; but when it is spoken of in the boiler house, it means simply the refuse, including dust and finer coal after the larger sizes have been separated. These larger sizes, including buckwheat and pea coal, command higher prices.

The refuse—strictly speaking, culm—is the fuel preferred by the manufacturers in Scranton, except where the haulage costs too much, when bird's-eye, buckwheat, or even pea coal are preferred; but all of the steam raised in this district is raised by the combustion of the products from the culm bank, and by far the most of it from the refuse or true culm.

Mr. William McClave, in comparing the fuel values of different fuels, rating egg, stove and chestnut coals of good quality at 100, places No. 1 culm at 78 and No. 2 culm at 70 per cent. By No. 1 culm is meant a mixture containing anthracite dust with Nos. 1, 2 and 3 buckwheat, and by No. 2 culm a mixture of dust with Nos. 2 and 3 buckwheat. According to his figures it would require 28·2 per cent. addition to No. 1 culm and 42·9 per cent. addition to No. 2 to make them equivalent in value to good quality egg or stove coal. By increasing the grate areas of the boilers, the boiler capacities, even with these low-grade fuels, need not be materially increased.

Sir William Thomson (now Lord Kelvin) enunciated the law for the most economical size of conductors for the transmission of electrical energy, that "the interest on the investment in copper should just equal the cost of the energy lost in transmission." This is known among electricians as "Thomson's law," but it has a very much wider application than that to electrical conductors. It is merely a specialization of the old saying that one must not spend more for economy than the economy amounts to, and is an economic law, applicable to all the affairs of life.

Applied to steam power, we see its application in this: If fuel be very expensive, we can afford to make a large investment in the way of improved boilers and engines, because by their use the saving in fuel may more than counterbalance the increased interest on the more expensive plant. The same plant which would be economical where fuel were dear would not be economical where fuel were exceedingly cheap, simply because of the fact that the saving of fuel effected by the expensive plant would not offset the increased interest charges on the more expensive plant. It is not necessary to follow this line of reasoning through all of its applications to the cost of power, but it leads to the conclusion, which is well verified by experience, and now recognized by our most advanced engineers, that where fuel is cheap it does not pay to go to extra expense to save fuel, viz.: it does not pay to go into extra refinements in steam engineering, because they cost more than they save.

Considering the question of original investment, therefore, simply from the fuel standpoint, it is apparent that the cheaper the fuel the less we can afford to pay for its saving. This means cheaper boilers and cheaper engines —less original investment and less fixed charges.

It is, however, only those favorably located, as regards the culm, who find it economical to use the cheaper grades. Where the fuel must be transmitted for a considerable distance by railroad, or even very short distances by wagon, it becomes more economical to use a better grade—such as No. 1 buckwheat, or larger—the simple transportation expenses being the controlling element as to which grade of fuel will be the most economical. It not infrequently happens, therefore, even in Scranton, which is as favorably located with regard to the culm piles as any city in the country, that the fuel costs the steam producers 50 to 75 cents, delivered in the boiler-house.

The only preparation which these refuse heaps require for their utilization for steam purposes is a proper sizing, and this is cheaply effected by passing the material over screens which separate it into the following: Pea coal passed through $\frac{1}{8}$-inch mesh and over $\frac{9}{16}$, occasionally $\frac{5}{8}$-inch; buckwheat, through $\frac{9}{16}$ or $\frac{5}{8}$-inch, and over $\frac{3}{8}$-inch; No. 2 buckwheat (rice, bird's-eye), through $\frac{3}{8}$-inch and over $\frac{3}{16}$-inch, occasionally $\frac{1}{4}$-inch; No. 3 buckwheat (barley), through $\frac{3}{16}$, and over $\frac{3}{32}$ or $\frac{1}{16}$-inch; bird's-eye, through $\frac{5}{16}$-inch, and over $\frac{1}{8}$.

Until the production of a suitable grate-bar was an accomplished fact, the fineness of the fuel was the main limiting quality in its use for steam production; but with the introduction of the rocking and dumping grate, of which the McClave is the best known and a type of its class, and the introduction of the blast in a sealed ash-pit, size has become far less controlling than uniformity of size; so that now mixtures containing nothing larger than No. 3 buckwheat, and extending down to as fine as dust, are successfully used.

With the finer materials there is, of course, even with these improved grate-bars, considerable loss in unconsumed

carbon in the ash pit; but this is far less than when unsized material, varying from, say, stove or egg down to dust is used; for in this case, when the smaller sizes have been entirely consumed, rendering it necessary on this account to dump the grate, the larger sizes have been but partially consumed, and go into the ash pit. In one case coming under the observation of the speaker, where unsized material was used, the ash pit contents consisted of from 30 to 40 per cent. of unconsumed carbon, and the economic results were even less favorable than they would have been had the finest sizes of culm, or the refuse after sizing, been employed.

It is almost the universal custom in the anthracite region, where culm is employed, to use a forced draught beneath the grate-bars. This is usually produced by means of a steam jet. The strength of the blast necessary for the most rapid combustion of the fuel is, however, such as to render it necessary to use the culm wet, otherwise the finer particles or dust would be carried bodily up the stack. The action of the steam, however, is beneficial in two ways. In the first place, it prevents the formation of clinker, or, rather, results in the formation of a clinker more friable—and hence more manageable—than would otherwise be the case; and, in the second place, it serves to make the fire-box a water-gas generator.

With the use of fine coal, however, comes the necessity of thinner fires and more frequent stoking, so that, with hand-firing, the proportion of the time when the fire doors are open is large, and this constitutes one of the chief disadvantages in the use of culm for steam-raising purposes.

Automatic stokers in abundance have been suggested and tried, in the hope of avoiding this difficulty, but until we can devise an automatic stoker which also has intelligence, it is doubtful whether this means will be fully effective.

There is one automatic stoker, however, that deserves especial mention. It is what is known as the Coxe automatic stoker, and is the result of a very careful study of the problem by the late Mr. Eckley B. Coxe and his assistants, at Drifton. (A picture of this stoker was thrown on

the screen.) For a description of it I am indebted to an excellent article by Mr. John R. Wagner, in *Cassier's Magazine* for November last, from which the illustration is taken. It consists essentially of a traveling hearth, which is fed continuously at one end and which discharges the ashes at the other.

Provision is made so that in the different stages of its progress, from charging to discharging end, the fuel is subjected to just such pressures of blast as are conducive to the best results. To effect this, the ash pit is divided into a series of chambers closed at the top only by the traveling grate. By the construction of the latter any material leakage from one of these chambers to the other is prevented, so that the pressures in each may be different. Mr. Wagner states that if, in the first chamber, the water-gauge pressure is 1 inch, the pressure in the next would be about $\frac{5}{8}$, in the next $\frac{3}{8}$, and in the next $\frac{1}{8}$ inch.

Furthermore, in order to regulate exactly the pressure of air in each of the compartments, the partitions are provided with registers, by the opening and closing of which the pressure in the air chambers can be varied to suit the conditions. The speed of travel of this grate varies usually between $3\frac{1}{2}$ to 8 feet per hour.

As to the economical results obtained from the last-named device, I have no figures, but with the confessedly imperfect methods of hand-firing, I find that a horse-power can be produced from culm for 365 days of 24 hours each, under favorable conditions, at Scranton, for about $22, and for a year of 313 days of 10 hours each for from $13 to $14.

Such, briefly, is the state of the art to-day in the utilization of anthracite culm piles for the production of power; but we are entering upon a new era which bids fair to throw even these admirable results into the shade.

Every handler of crude products finds that it is advantageous, to a greater or less extent, to prepare his product for market. The coal miner, especially the anthracite coal miner, finds that, by sizing his coal, it is more marketable than when he does not; hence, hard coal can be bought in sizes to suit the customer. When a waste product seeks a

market, it must be in such a shape as to commend itself to the public, or it will be rejected. It has already been shown that the culm yields better results when separated into individual sizes than when used without this separation; but a further preparation, if the cost be not too great, would render it still more valuable.

Metallurgists have long realized that a gaseous fuel is the ideal, and modern science has demonstrated that materials so poor in combustible matter as to be unutilizable directly for the generation of steam, may be converted into gas, and in this form constitute a most concentrated and valuable fuel. The most noteworthy early advance in this line was the conversion of bituminous matters into generator gases, very poor in intrinsic fuel qualities, but which, by the utilization of the regenerative principle, gave rise to a steel process—the Siemens-Martin open hearth steel process—which depends for its success upon high temperatures, hitherto not possible with the best of fuels.

Producer gases of this kind, however, were incapable of transmission to any considerable distances because of the large percentages of condensable products which they contained, and *had* to be used hot. They were not, therefore, commercial fuel gases.

The water gases produced from coke, anthracite and other non-bituminous fuels, of which the Lowe and Strong processes were among the pioneers, introduced a new era of fuel gas manufacture, because they could be produced cheaply and transmitted without condensation.

The general outline of the water gas manufacture is briefly this: a jet of steam is passed up through an incandescent bed of anthracite or coke. The steam is decomposed by the incandescent carbon, the oxygen of the steam going to the carbon, forming carbonic oxide (a combustible gas), and the hydrogen being set free. This process in a short time reduces the fire to such an extent that it must be blown up with an air jet before gas can again be produced, so that the process is an intermittent one. It, however, gives a gas of great calorific power at little cost, and this, when purified and enriched, is largely used as an illuminating gas in many

of our cities, Philadelphia being among those, I am told, which use gas of this kind.

For fuel purposes, however, it is necessary that the gas be even cheaper than this water gas, unrefined and unenriched, and, as a further requisite for its successful manufacture, it is necessary that the process should be a continuous and not an intermittent one.

To Mr. J. Emerson Dowson, of England, is usually given the credit of having first met this want by combining the steam and air blast so as to make the process a continuous one. The resulting gas, though a much poorer one than that resulting from the usual water gas processes, is still cheaper per unit of calorific power, and strong enough for gas engine use. Many others have followed in the steps of Dowson, among whom may be named Lesscauchez and others, but this class of fuel gas is generally known as Dowson gas, and the best known and most used producer is still Dowson's.

The process is simply this: The non-bituminous fuel—either anthracite or coke—is burned in a furnace with blast produced by a steam injector properly regulated so as to produce as little carbonic acid as possible. Dowson prefers to superheat his steam, but uses his air at the atmospheric temperature. To superheat his steam he requires a small auxiliary furnace, but some others do without the superheating (and, consequently, the auxiliary boiler) by relying upon the evaporation of water introduced into the ash pit for the moisture to produce the water gas.

Gases manufactured by any of these continuous processes are necessarily admixed with all of the nitrogen of the air, but the average Dowson gas, notwithstanding this dilution, has a fuel value of about one-quarter of that of ordinary 16 candle-power illuminating gas. One ton of good anthracite coal will produce from 150,000 to 160,000 cubic feet of this gas.

Where anthracite costs $4.50 per ton, Dowson gas costs about 6 cents per 1,000 cubic feet to manufacture.

It is not necessary, however, that we use the best of fuel; for, so long as it is capable of supporting combustion, it is adaptable to the manufacture of Dowson gas, a fair analysis

of which, at 32° F. and 14·22 pounds pressure, is about as follows:

	Per Cent.
CO_2	3·40
O	0·9
H	16·47
CO	27·50
N	51·73
	100·00

When we consider that in the above assumed figures all other costs than fuel amount to about 3 cents per 1,000 cubic feet of gas produced, the possibilities with cheap fuel, such as the culm banks afford, suggest themselves at once.

When we also consider the facility of transmission afforded by a prepared gaseous fuel of such concentration as this, and the economies attending its use as compared with that of solid fuel, the further suggestion obtrudes itself that the conversion of the culm into gas at the culm piles, and its transmission in this form to the point of consumption, would be the proper method to pursue.

But let us compare the cost at various steps. Mr. Dowson estimates the cost of gas producers on a fairly large scale at about $11 per horse-power. I presume that this includes his own services, for I am sure that they can be built for less than that in this country; but even at this cost they are cheaper to install than boilers.

Now as to transmission. We know that those unfavorably situated as regards the culm piles, even in Scranton, cannot advantageously use the cheaper grades of culm by reason of the haulage charges. It has been suggested that the culm be burned under boilers at the banks and its energy transmitted electrically; but many of my audience will be surprised to learn, perhaps, that electricity is not our cheapest method of transmitting energy. We can economically transmit coal by railroad very much further than we can the equivalent energy by electrical means, and yet we cannot transmit this culm more than a short distance, even in this way, and have it an economical product when delivered.

As illustrating the relative economies of gaseous and electrical transmissions, the late Mr. Denny Lane, an English gas engineer of prominence, once stated that, with ordinary 16 candle-power gas, 3,000 horse-power could be sent a distance of 1 mile for an expenditure of 1 horse-power—an economy of distribution far exceeding that possessed by any other system, being only $\frac{1}{30}$ per cent. of the power conveyed.

With respect to the cost of mains, he says, taking the cost of conductors laid on the low-pressure culvert system at £5,500 per mile for the conveyance of 1,080 ampères, and assuming an electromotive force of 110 volts, the power would be 158 horse-power. It would, therefore, require, he says, two pairs of these conductors to convey 300 horse-power, whilst a 6-inch main, with ordinary gas, would convey sufficient gas for that power at 4 inches pressure, and at 16 inches pressure would deliver as much as four pairs of such conductors. The 6-inch main, he says further, would cost £500 per mile, while two pairs of low-pressure conductors would cost £11,000, and four pairs would involve an expenditure of £22,000 per mile.

The lecturer has found, by calculation, that to transmit this power to the distance named, at 220 volts, the metal in the pipes would cost considerably less than the metal in the conductors. Contrast this with electrical transmission, in which 10 per cent., or 300 horse-power, would be an allowable loss, and we see how the gas transmission has the advantage over the electrical.

I also find that a 6-inch pipe will deliver 6,000 cubic feet of illuminating gas per hour at a distance of 10,500 feet under 4 inches of water pressure. If this be 16 candle-power gas, and be used in a gas engine, allowing 25 cubic feet per horse-power hour, this quantity represents 240 horse-power.

Cast-iron pipe, 6 inches in diameter, having a thickness of $\frac{1}{2}$ inch, weighs 31·9 pounds per foot. The total weight of this 2 miles (nearly) of pipe will, therefore, be 334,950 pounds. This would be equivalent in conductivity to about 41,869 pounds of copper equally distributed over the same

distance. But 4 miles of copper, weighing 41,869 pounds, would be equivalent to about four No. 000 B. & S. wires, which would have a resistance for the 4 miles of 0·325 ohm. If the charging current were transmitted at 220 volts, there would be required a current of 848 ampères; but a wire having a resistance of ·325 ohm will only deliver under a pressure of 220 volts; 220 ÷ ·325 = 677 ampères; there would, therefore, be required five No. 000 B. & S. wires to deliver this energy, and the weight of this would be 53,540 pounds.

If the distribution took place at 1,000 volts, the ampères required would be approximately 180. To deliver this at the same distance with a loss of 10 per cent. would require 6,264 pounds of copper, and to deliver it at 1 per cent. loss would require 62,642 pounds, which would cost far more than the pipe, and still give less efficient transmission.

When the fuel is delivered in this form, it is adaptable to all of the uses to which fuel is ever applied. It can be burned under boilers for the raising of steam for power or heating purposes, or it can be applied to domestic uses, or it may be used directly to advantage in gas engines. In no case need there be any stand-by losses, such as are inevitable with solid fuels; for when the fires are wanted it is only necessary to turn on the gas, and when they are no longer needed it may be turned off, and there are no ashes or coal to be handled.

For power purposes, a somewhat extensive investigation of the question has satisfied me that, if we can procure cheap gaseous fuel, the gas engine is the proper thing to use, especially in situations such as are found in our electric lighting stations and elsewhere, where the load is variable between wide limits.

In such situations a portion of the boiler plant must lie idle during the hours of light load, and it has been estimated by very competent authorities that the consumption of coal of the idle boilers amounts to 10 per cent. of the total consumption of all the boilers.

With the gas generator the stand-by losses are so small as to be negligible in comparison, so that a direct gain in economy is here attained.

I believe that all of the English gas engine manufacturers will guarantee their engines, even in comparatively small sizes, to produce a brake-horse-power-hour, when using Dowson gas, on 1¼ pounds of anthracite coal or less. It is seldom that our largest compound condensing steam engines are found to give equally good results.

In view of these facts, there are many, myself included, who believe that the problem of utilizing the culm accumulations is to be solved by the conversion of this culm into a cheap fuel gas at the banks, and its transmission thence in pipes to the point of consumption, or to centers of distribution by other more convenient means.

I believe, although I have not attacked this problem from the numerical side, that it would be economical to pipe this artificial gas to Philadelphia from the nearer coal fields. I know, however, that it would be more economical for your electric lighting and power companies to convert their fuel into gas on the water front, and distribute it thence in pipes to gas engines favorably located as to distribution, than to cart their coal to these centers, pay rent or interest on the investments required for boiler and coal storage room, and other attendant expenses.

The only question in my mind is whether it would be cheaper to manufacture the gas at the culm pile and transmit it in pipes to the water front, or to transmit the better grades of fuel in the solid form to the latter point, and there convert it into a gaseous fuel.

We have seen that in the Dowson gas about half of it is nitrogen, which is inert and acts as a diluent to the fuel value of the gas. If there were any way of absorbing this, it would be a great boon to the fuel gas manufacturer, since it would enable him to send to market a still more concentrated fuel. But nitrogen is singularly inert and we know of no ready absorbant of it. The nitrogen compounds, such as the cyanides and ammonia salts, are, however, exceedingly valuable and in almost unlimited demand. If it were possible to chemically combine this nitrogen of the fuel gas, therefore, we would "kill two birds with one stone"—enrich our gas by the removal of a diluting element, and have as a by-product a commercial product.

Many attempts have been made to accomplish this end, none of them, however, as yet reaching the commercial stage.

I have very recently had the opportunity of visiting the latest experimental plant designed for this purpose—that of the Fogarty Gas and Chemical Company.

According to Mr. Fogarty's theory, nitrogen, when heated to 1,900° to 2,000° F. in the presence of nascent carbon and an alkali, forms a cyanide of that alkali. The general method of operation is to produce a carbonic oxide combustion of the fuel by means of an air-blast sufficiently highly heated to produce the temperature required, and also to decompose a rich hydrocarbon gas supplied above the zone of combustion. The cracking of the hydrocarbon results in the liberation of carbon, which, in its nascent state, unites with the nitrogen to form cyanogen, and this, in the presence of the alkali, is at once fixed as an alkaline cyanide.

It is claimed that if but 3 per cent. of the nitrogen can thus be fixed, the resulting products will be more valuable than the gas, pay the entire expense of its manufacture, and yield a nice profit in addition.

The success of this process on a commercial scale has not yet been demonstrated, but a plant of considerable size, intended to demonstrate this, is now nearly ready for test. Should it prove successful, as we must all hope it will, it will be but another striking illustration of the utilization of waste products.

A process, such as this, which will give us a commercial product from an undesirable constituent of our fuel gas, will cheapen the latter and add a large increment to the value of that other hitherto waste product, the culm pile.

As the conversion of coal into gas for fuel purposes is bound to replace its use in the cruder condition, so will any such additional process, as that which renders possible the commercial fixation of the nitrogen of the fuel gas, supplant processes which do not accomplish this end. That which is fittest will survive.

ENGINEERING AS EXHIBITED ON THE GREAT LAKES.*

By JOHN BIRKINBINE,
Member of the Institute, Past President Am. I. M. E., etc.

[*Concluded from vol. cxli, p. 447.*]

LAKE HURON.

Lake Huron has abundant evidences of engineering ability in the railroads and industries of Detroit and Port Huron, the lumber mills and salt wells of Michigan, etc., while the Government work of improving the connections with other lakes offers much of interest. However, the unique feature is the *St. Clair Tunnel*, extending from Port Huron, Mich., under the St. Clair River, to Sarnia, Ont., and connecting the Grand Trunk Railway system of Canada with the Chicago and Grand Trunk Railway, completed at a cost of $2,700,000. The tunnel proper is a continuous metal tube, 19 feet 10 inches in diameter, and 6,025 feet, or more than a mile long. The length of the approaches, in addition to the tunnel proper, is 5,603 feet. As one passes through the Egyptian darkness of this great engineering work seated comfortably on a car, and realizes that in the waters above him float annually a greater tonnage than enters the port of Liverpool, the achievements of the engineer are emphasized.

LAKE ERIE.

Lake Erie, the shallowest of the Great Lakes, has, in its cities of Buffalo, Dunkirk, Erie, Cleveland, Ashtabula, Loraine, Sandusky and Toledo, much of interest in their harbor improvements, public works, industries, etc.; but none are more instructive than the ship-building establishments, and the great iron ore receiving docks, which have carried in stock at one time nearly 5,000,000 gross tons of iron ore. At these docks buckets of ore are raised from the holds of vessels and delivered 300 feet distant, on stock piles or on cars, at a cost of less than 1 cent per ton.

* A lecture delivered before the Franklin Institute, December 6, 1895. The lecture was liberally illustrated by a large number of lantern slides.

THE LAKE MARINE.

A feature of the improvement in the lake marine is emphasized by constantly declining freight rates; thus, iron ore, which commanded $1.75 in 1887, was carried eastward in 1894 for 70 cents per ton; coal was transported in the opposite direction for 90 cents in 1887, and 40 cents per ton in 1894; the rate on flour—29 cents per barrel in 1887—was reduced to 24 cents in 1894, while the grain rate in the same time fell from 7 cents to 2½ cents per bushel, and the lumber rate was reduced from $4 to $1.90 per 1,000 feet. The minimum prices show the possibilities, for freights were exceptionally low in 1894 and in the first half of 1895; but notwithstanding later advances, there has been a decided cheapening as larger and faster vessels and better terminal facilities were supplied.

It must be remembered that the statements concerning traffic through the St. Mary's Canal merely cover that originating on or destined for Lake Superior, the commerce of the entire lake system being two and one-half or three times as great; but the immense quantities which are handled through the locks represent but about seven months' business, for the severity of the climate closes navigation on the upper lakes from the end of November to the first of May. It is doubtful whether this period will be lengthened, although suggestions have been made to keep a channel open by powerful boats, similar to those used to transport railroad trains across the Straits of Mackinac.

The *St. Marie*, the newest addition to the fleet of ice fighters, has a length of 300 feet and weighs about 3,000 tons. It is equipped with engines of 4,500 horse-power, and has a 14-foot propeller in each end. This boat has traveled through ice 2 feet thick, at a speed of 8 miles per hour, and has crushed through immense floes.

The United States Commissioner of Navigation, on June 30, 1895, reported 1,755 steam, 1,100 sail and 487 unrigged United States vessels, with a tonnage exceeding 1,250,000, enrolled in the lake customs district. He also shows that during the year there were 22 large merchant vessels, averaging about 2,500 tons each, built in the United States, of which

11 were constructed on the lakes, 10 on the Atlantic and Gulf, and 1 on the Pacific coast.

Thirty vessels, aggregating a tonnage of 100,000 tons, are under construction in the shipyards on the lakes. Among the later contracts is one made at Detroit for three car-transfer boats for the Trans Siberian Railroad, to be used on Lake Baikal, in central Siberia.

Passenger Steamships.—Within late years, the character of the lake marine has been greatly improved by larger vessels, many constructed of metal and supplied with machinery of the highest economy. Being used exclusively for passenger service, the new steamships *Northwest* and *Northland* are considered queens of the lake marine; but some of the vessels constructed for the iron ore trade are equally good specimens of marine engineering, and of equal size. The two passenger boats above mentioned (the only water-tight compartment steel vessels now on the lakes with quadruple expansion engines and twin screws) are 400 feet long, and have a displacement of 4,500 tons. The two engines on each vessel can develop 7,000 horse-power, and are supplied with steam by twenty-eight Belleville boilers. This equipment drives these boats from Buffalo to Duluth, 1,000 miles, in sixty-five hours, making four or five stops. When the shallow places in the rivers connecting the lakes are deepened, and the new locks are in use, it is expected that the time of travel can be materially reduced.

Freight Steamships.—One of the largest freight vessels now plying on the lakes is the *Victory*, a steamer which has the following dimensions: 380 feet keel, 400 feet over all, 48 feet moulded beam, and 28 feet moulded depth. The depth of her water bottom is 66 inches. The best indication of her cargo capacity is her first load, which was 3,689 gross or 4,132 net tons of iron ore, taken from Two Harbors to Cleveland, on a draft of 14 feet 3 inches. Clear open deck facilitates the handling of cargo through numerous hatches.

Other vessels of as great size are now being constructed, although there is a wide difference of opinion among navigators as to the advantage of these in the

present tortuous and shallow condition of some of the channels and rivers. The *Victory*, although a new vessel, has made some remarkable records for quick dispatch; its cargo of coal bound west was loaded in ten hours, at the rate of 400 tons per hour, and unloaded at the head of the lake in fifteen hours. It was loaded at Two Harbors, Minn., with iron ore in five hours, the rate of loading being 800 tons per hour, the ore being unloaded and placed on cars at Ashtabula at the rate of 560 tons per hour. As in unloading, all the material must be shoveled into buckets, this record is remarkable. When engaged solely in the iron ore traffic, bringing only east-bound cargoes, this vessel receives its load of about 4,000 tons of ore at Two Harbors, Minn., travels to Cleveland or Ashtabula, discharges its cargo, and returns light, ready for another cargo, within seven days; but if a load of coal is taken westward, the time of taking on and discharging this cargo and the slower progress made increases the round trip to ten days.

The *Zenith City*, a sister ship to the *Victory*, but somewhat larger, is constructed throughout of steel, the channel system of construction being used, instead of plates and angles. Her length is 405 feet, beam 48 feet, depth of hold 28 feet. The vessel is driven by triple expansion vertical engines, 22-inch, 38-inch and 63-inch cylinders, stroke 40 inches, and equipped with water tube boilers. The vessel cost $225,000, and carried one cargo of 138,000 bushels of wheat.

The *Rappahannock*, a wooden freight screw steamer, the *Marine Review* states, measured: length over all, 335 feet; beam, 43 feet; depth, 26 feet; displacement at 15 feet draft, 2500·6 tons. The engines are triple expansion, 20, 32 and 54 inches diameter by 42 inches stroke. The boilers, two in number, are 12 feet 3 inches diameter by 12 feet long, for a working pressure of 160 pounds. Each boiler has two 42-inch furnaces and 314 tubes of 2½ inches diameter. The total grate area is 84 square feet, and total heating surface 3,786 square feet. With a cargo of 80,000 bushels of wheat, or 2,400 net tons, from Duluth, on a draft of 14 feet 4½ inches, a test was made under regular working conditions. The coal used was ordinary run of mine, costing about $2

a ton at Lake Erie ports. The boiler test extended over ten hours. For four hours and fifteen minutes indicator cards were taken from the engines every fifteen minutes, and also readings of meter, temperature, steam, vacuum and revolutions; during the balance of test every thirty minutes. The fuel and water consumption per indicated horse-power are, therefore, referred to the time during which observations were made most frequently. The moisture in coal was found by placing a carefully weighed quantity over the boilers and allowing it to dry for about sixteen hours.

The record showed:

Speed per hour, miles per log, mean	12·75
Revolutions per minute, mean	85·08
Steam pressure at throttle, mean	153·5
Vacuum, mean	21 inches
Indicated horse-power, mean	1,167·34
Total coal burned, pounds	20,255·
Per cent. of ashes	8·59
Per cent. of moisture in coal	4·
Water evaporated per pound dry coal, pounds	8·04
Water evaporated per pound combustible, pounds	8·76
Dry coal per hour, pounds	1,944·48
Feed water to boilers (during engine test), pounds	70,103·75
Coal per indicated horse-power per hour, pounds	1·75
Combustible per indicated horse-power per hour, pounds	1·4
Water per indicated horse-power per hour, pounds	14·07
Water per indicated horse-power per hour, pounds (auxiliaries deducted)	13·07
Indicated horse-power per square foot of grate	13·89
Coal per square foot of grate per hour, pounds	24·11
Ton-miles per hour	30,600·
Coal per ton-mile, ounces	1·01
Miles per ton cargo for 1 cent fuel	157·2

This is equivalent to carrying 1 ton 1 mile for $\frac{4.3}{100}$ of a mill, at the rate of 12·75 miles per hour.

An interesting point is a comparison of the efficiencies of the plant as between Lake Erie and Lake Superior. The observed temperature of the water of Lake Erie was 73·5° to 75° F.; consequently it was almost impossible to obtain a better vacuum without the use of excessive quantities of injection water. With the same or even a less quantity of

injection on Lake Superior, where the water temperature was 45°, it was possible to obtain 24 inches vacuum. The increase in indicated horse-power would be easily 125, which would not cost 1 cent, and the apparent fuel and water consumption per indicated horse-power would be reduced nearly 11 per cent.

Whalebacks.—The advances in shipbuilding on the Great Lakes has been referred to, but such reference would be incomplete without mention of the special constructions, the "whalebacks" and the steel canal-boats. The shallow waters in the rivers caused vessels to be constructed of lengths and breadths disproportionate to depths, so as to have large carrying capacity, and the number of hatches to facilitate prompt loading and unloading had a tendency to weaken the structures. An outgrowth of the lake marine to meet the existing conditions was the "whaleback," which has been sufficiently satisfactory to encourage the construction of a fleet of forty of these oddities.

The "whaleback," although familiar to those who traverse the Great Lakes, dates back but seven years, in which interval fifteen steamers, with an aggregate carrying capacity of 36,000 gross tons, and twenty-six consorts, capable of carrying 60,000 gross tons, have been constructed. This tonnage is based upon present available draught of 14 feet 6 inches; when this draught is increased to 18 feet, the existing fleet of whalebacks can carry 125,000 gross tons. Four more of these vessels, each of about 5,000 tons, are now under construction. One was built in England, and one on the Pacific Coast; and it is claimed that but one of these vessels has been lost, for which gross carelessness is charged.

Having so little superstructure, the whalebacks drift less than the ordinary vessel, and the rounded deck and stem assist their easy riding in a heavy sea. The builders estimate that a whaleback will carry 20 per cent. more cargo than other vessels with the same amount of dead weight, framing and plating being equal. During the season of 1895, one of the steam whalebacks, towing two consorts, made nineteen round trips of an average of 1,720

miles each, and delivered fifty-seven east-bound cargoes, aggregating 131,785 gross tons, besides carrying a considerable amount of west-bound freight; the consumption of coal for the season was 5,403 net tons. Another one of these steam whalebacks, with two, and sometimes three, consorts, made seventeen round trips, delivering fifty-four east-bound cargoes, amounting to 126,389 gross tons, on a consumption of 4,585 net tons of coal. The engines on these steamers are triple-expansion, of 1,000 horse-power, supplied by Scotch boilers.

The above figures show that this work was performed with a consumption of $\frac{4}{10}$ ounce of coal per ton-mile for the round trip, which, equated for the east-bound trip only, would show $\frac{1}{2}$ ounce per ton-mile. See *Fig. 4*.

Steel Canal-Boats.—The steel canal-boats are a late innovation, intended to convey heavy freight through the lakes and the Erie Canal. They each carry about 200 tons and travel in fleets, one boat with engine pulling a number of consorts.

Another interesting feature of ship-building on the lakes is the practice of launching vessels sideways.

Improvements for Navigation.—The Government has expended large amounts in improving the waterways connecting the Great Lakes, but liberal appropriations will be required to place them in condition to pass vessels drawing 20 feet of water, for to-day adverse winds may prevent vessels, when loaded so as to be within the limit of the present canal (16 feet), passing shoals; in fact, few risk over 14 feet 6 inches draught.

Those engaged in commerce on the lakes jealously watch every increase or decrease in depth, and considerable interest has followed the proposal to withdraw from the lower end of Lake Michigan from 5,000 cubic feet at a minimum to 10,000 cubic feet at a maximum per second through the Chicago Drainage Canal. Estimates are made that the average reduction of the level of Lake Michigan from this cause will be between 3 and 4 inches, reducing the carrying capacity of the lake fleet, and consequently its earnings, over $500,000 annually.

With 90,000 cubic feet per second pouring from Lake Superior into the great reservoirs of Lakes Huron and Michigan, the diversion of the amounts above-named would at first sight seem insufficient to affect the level, without considering the streams naturally tributary to these lakes.

A late prophecy comes from across the ocean that the deepening of the waterways of the great lake system will force new ports to be formed, basing this assumption upon the shallow waters in the harbors and rivers of the important lake cities, to deepen which will jeopardize the foundations of warehouses, etc., constructed at or near the dock line. Such an emergency may face a few localities, but the energy which has developed the enormous lake traffic will find means for keeping it.

Congressional action is being asked to secure an investigation of the possibility of raising the water level of Lake Erie by a dam near Buffalo, which will not only deepen all harbors on this lake, but improve navigation on the Detroit River and possibly on St. Clair Lake and River.

The great iron and steel industry, which has achieved renown for its output and economies of production, the shops which turn out vessels and machinery magnificent in design and proportion, the varied manufactories, the unique bridge work, the municipal improvements, etc., have all been passed by in this imperfect chronicle.

One might continue a journey from Lake Erie through the Welland Canal, which passes moderate draught vessels across the Canadian peninsula to Lake Ontario, a descent of 325 feet, then through Lake Ontario and down the canals of the St. Lawrence River, finding continually evidences of engineering skill; but these must be passed by, to close an incomplete *résumé* by calling attention to the water-power, much of which may be, and a very little of which is, harnessed for service, and the possibility of connecting the Great Lakes with the seaboard.

WATER-POWERS.

The shores of Lake Superior and portions of some of the other Great Lakes are not level plains, but for the greater

part rise rapidly, hence there are numerous cascades and waterfalls. One of the most promising of these is the St. Louis River, entering Lake Superior at its westernmost point. Here in 10 miles the river falls 440 feet, and delivers, from a drainage basin of 4,000 square miles, from 1,200 to 2,400 cubic feet of water per second. Thus at the western extremity of the present navigation is a large water-power of 40,000 horse-power awaiting improvement, while at the eastern end is the Falls of Niagara, the partial utilization of which is now looked upon as opening a wide field for the economical development and transmission of electrical power.

The possibility of making some deepwaterway connection between the Great Lakes and the Atlantic Ocean has been discussed for a number of years, and similar projects for uniting the waters of the Mississippi and the Ohio with the Great Lakes have been brought forward. At present the Chicago Drainage Canal is the most advanced step towards securing the latter, although a survey has been made to reach the Mississippi River above St. Paul and Minneapolis from the head of Lake Superior, and a commission is now engaged in discussing canalization schemes for uniting Lake Erie and the Ohio River. Canals to make a more direct connection between Lakes Superior and Michigan, and between Lakes St. Clair and Erie, are also proposed. A project, bold in its conception, is advanced, which, by deepening the summit level of the Welland Canal or by cutting a new canal in the State of New York around Niagara Falls, and by deepening the St. Lawrence Canals, connecting Lake Francis and Lake Champlain by a new canal, and Lake Champlain with the Hudson River by a new canal, is to provide deep-water transportation between the Great Lakes, Montreal and New York. Instead of the numerous locks of small depth, it is proposed to employ locks of 150 feet or more lift, operated by compressed air, the vessels being carried in metallic basins superposed upon immense air cylinders. The attention which is being given all over the world to schemes of canalization and river improvement point to an appreciation of

the value of water transportation; and although it may seem visionary, it is not improbable that the engineer will yet accomplish the desired result of transferring large vessels from the lakes to tide-level. A region which has developed so many surprises could well afford to add this to the list. In fact, an International Deepwaterways Commission is now organized to consider such projects.

Joint Meeting of the Chemical and Electrical Sections, May 26, 1896.

RETURN CIRCUITS OF ELECTRIC RAILWAYS.

By Charles Hewitt.

Electric traction began its rapid progress in the year 1887. The first roads, with the exception of that in Richmond, were mostly suburban lines, or were located in the smaller cities. It was not until the larger cities began to adopt electric traction that the electrolysis of iron pipes began to show itself; not until the summer of 1891 did this trouble take any definite shape.

The Erie Motor Company, Erie, Pa., experienced much trouble with the water pipes in its station; the company also had complaints from the plumbers in town that the service pipes were rapidly being corroded. I made an examination of this plant and others in Pennsylvania, and found a very bad state of affairs. At that time it was not definitely known that the trouble was due to electrolysis; in fact, as most of the trouble was confined to the station, it was supposed that the trouble was due to bad feed-water. I found rail bonding very poor. In some places there were no bonds at all. I also found the positive pole connected to the pipes and track, the negative pole being connected to the trolley wire. At that time a considerable number of roads were connected in this manner. On investigation I found that 40 per cent. of the total output of the station was carried by the pipes, and it was soon very evident to me that the trouble was an electrical one, pure and simple.

In the course of a few months various notes began to be published in the different papers in regard to trouble with water pipes; but it was not until Mr. Farnum, of Boston, read his paper before the American Institute of Electrical Engineers that the trouble was placed before the public in any precise form, although it was well understood by the companies manufacturing railway apparatus for months previous. From that time to the present, much has been written and many suggestions made, and a large amount of data collected, so that at the present time I believe we are in shape to contend fairly with the disease.

In considering this subject it will be well, in the first place, to inquire what causes electrolysis, and why are we troubled by it. Various explanations have been given, and I must confess that at the present time I am not able to answer the question positively. One thing is certain, namely, that it takes place more rapidly in salty earth than in dry sandy soil. Copper return wires in dry sand have remained apparently unaffected for years; whereas, similar wires buried in the soil of Salt Lake City will scarcely last three months. In the case at Erie, previously cited, much of the trouble was in water pipes which were suspended in the air and showed the corrosion on the inside. Whether the corrosion was due to nascent gases or to the decomposition of salts, I am not prepared to state; it seems evident, however, that moisture in some form is necessary to cause the trouble, and I believe that the most destructive element is the nascent oxygen. Our text books, however, say that it takes a pressure of nearly 2 volts (1·47 Gore) to decompose water; whereas, Prof. Jackson has proved conclusively that a mere directive force is all that is necessary to cause electrolysis; and to my knowledge electrolysis has very rapidly taken place under pressure of less than 1 volt.

The electrolytic action is quite characteristic and is very easily distinguished from ordinary corrosion. You will see by the samples here exhibited that there is a decided pitting of the surface of the metal, whereas the corrosion of an ordinary rusted pipe is of a fairly uniform character. This pitting, I presume, is due to the fact that

the metal is not perfectly homogeneous, and that the purer iron is the most readily attacked.

It is somewhat amusing, at the present day, to recall the fact that, in the year 1887, the earth and rail-return were considered as zero resistance; we know, at the present day, that this is so far from the fact, that the rail-return problem is one of quite as great importance as the feeder problem.

Now, why does electrolysis bother us at all? In considering this, we must look upon rails and the pipes as two separate systems of conductors, which, in their normal condition, are slightly insulated from each other by a layer of earth. If, therefore, the track were of zero resistance, or the insulation between the track and the pipes were of infinite resistance, it is very obvious that no current would leave the rails and enter the pipes. Unfortunately, neither of the conditions can be perfectly realized. The actual conditions can be shown more clearly by *Fig. 1*. In this, for

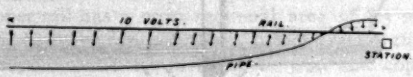

FIG. 1.

simplicity's sake, we will assume a straight road with the station at one end, representing the track by the heavy straight line; we shall assume, also, that, between the far end and the power house, there is a drop of 10 volts. Now, with any such drop in the track, and with a system of piping below the track forming a fair conductor on account of the very mass of the material, it is very evident that some of the current will seek this path, and more or less will be thus diverted in proportion to the drop in the rail.

Referring again to *Fig. 1*, I have endeavored to show the condition of the pipe in reference to that of the track by the curved line. At the outer end it is very evident that the potential difference between the rail and the pipes would be a maximum, assuming, of course, that the trolley wire is positive, and that the current is flowing towards the station. This difference in potential will gradually decrease as we approach the station, until we reach a point where

the drop in the track and the drop in the pipe, together with the resistance between rail and pipe, combine to form a neutral point; from this point out there can be no electrolysis of the pipes (except at local points); but as we approach near to the station, the potential of the pipe begins to rise above that of the track, and it is just here that we may begin to look for trouble.

The electrolytic action takes place only at the anode or positive pole. The region between the station and neutral point we will call the danger area, and our sole concern is to protect the pipes in this region. Now, how shall this be done? It is very obvious at the outset that we must straighten out the curved line in *Fig. 1*. In other words, we must make the pipe negative to the rail at all points.

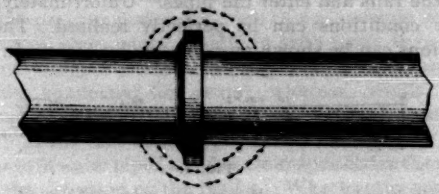

FIG. 2.

So far, I have assumed that no connections have been made between the rail and the pipe. Many engineers have recommended the connecting of the pipes and the rail-return, and I believe there are to-day advocates of this scheme, but, to my mind, the suggestion is utterly preposterous. Why aggravate our trouble by inviting currents into the pipe, when we have sufficient trouble from the currents which enter the pipes uninvited? Ordinary gas and water pipes have not been laid with the view of being utilized as electrical conductors; they become good conductors simply from the very mass of iron of which they are composed. The joints, however, are anything but perfect metallic unions, and although these may transmit small currents with impunity, if we force larger currents through the pipes, we will get a drop at the joint, which will give

us a condition shown in *Fig. 2*, in which the drop in the joint is supposed to be sufficient to overcome the resistance of the earth around the joint and cause some of the current to flow around the outside. This condition, as you will see, will cause a local danger point at one side of the joint. To me it seems just as reprehensible on the part of a railway company to appropriate the pipes of the water and gas companies as an annex to their system, as it would be to appropriate the conductors of another electric company.

The position of the engineer is now very clear, and may be stated as follows: Do not invite current into the pipes, but take care of all that comes in uninvited; in other words, keep pipes and return system as distinct from each other as possible, and make the resistance of the track system as low as possible.

We are now in a position to take up the various devices that have been suggested for overcoming the trouble. Naturally, our first consideration is a perfect rail bond. A 60-pound copper rail has a cross sectional area of 8·3 square inches, which, at the ratio of 7 to 1—which ratio is the one usually given for the conductivity of iron and copper—would be equivalent to a conductor of 1,500,000 circular mills. Since, however, our rails are made of comparatively high-carbon steel, I am inclined to think that the true ratio is nearer 10 to 1, which would make the rail equivalent to a bar of 1,050,000 circular mills copper.

When we realize that there are two rails in each track, and that all the ramifying tracks in a large city like this are connected together, we begin to realize what an immense mass of electrical conductors the tracks present. It would be very injudicious, therefore, and a needless expense to abandon the tracks as conductors.

Mr. J. H. Vail advocates the use of the return feeders to an extent which practically eliminates the track as a conductor, and I believe he has patented a system of track feeders which is the counterpart of the ordinary system of feeders used in lighting and railway work; and he proceeds to figure the drop in the return feeders in the same manner that he would figure the drop in the positive

feeders, eliminating the track from consideration. A system of this kind is needlessly expensive, for reasons which I have already shown. If the track be well bonded there is no necessity for an elaborate system of track feeders. In some of the smaller roads, no track feeders whatsoever are necessary; in the larger roads, such as we have in this city, there are many places where the current density becomes so great that it is advisable to augment the track by the addition of a proper amount of copper; in fact, all track in the city should be protected by a smaller or greater amount of copper, in order to guard against broken bonds, as well as to provide a better conductor.

A modification of the Vail system of track feeders consists in running a copper cable or bar in a trough filled with insulating material and parallel to the track. This conductor should decrease in size as it gets farther away from the station. There is no doubt in my mind of the advisability, in all cases, of protecting the return cable with a moderate amount of insulation. Experience has proved, time and time again, that an unprotected copper conductor laid between the rails is very liable to be reduced to a state of "innocuous desuetude" by the very action it is intended to prevent.

Both of the above-described systems of return feeders will reduce the liability to injury to the pipes, but will not entirely prevent it; in other words, unless the copper is infinite in amount, we will still have a danger area in the vicinity of the power station. Our care, therefore, should be to provide an amount of copper for the return which shall be in accordance with the demands of each individual road; and, in addition, we must provide a means of protecting the pipes within the danger area. The first, and, perhaps to the present day, the best, suggestion which has been made was that presented by Mr. Farnum, in the paper previously cited. This consists in running one or more return feeders to all the pipes which show a potential positive to the track or return cables. This return feeder must have no direct connection with the other return feeders, except at the negative bus bar, and must be of sufficiently

low resistance to bring the potential of the pipes at least down to that of the tracks at each point between the power house and the danger line.

I am well aware that, in many cities, the track bonding is very inferior, and also that the tracks have been bonded to the pipes. Both of these will aggravate the difficulty of reducing the potential of the pipes by the separate return feeders; but if the road be well bonded and no connections have been made between pipe and rail, the matter becomes quite easy of solution. I have been informed by the very highest authority that, of the output of 8,000 ampères in one of our Eastern cities, 5,000 ampères is returned by the pipes. Is it any wonder that the city authorities object? In contrast to this, in three stations in this city, which I have personally tested, I find that, in a station with an output of 3,000 ampères, the maximum returned by the pipes was 50 ampères, or $\frac{1}{60}$ of the total output. In the other two stations the ratio between the output and the main return by the pipes was practically the same, namely, $\frac{1}{80}$ of the total output. You will readily see that we have here a much easier problem to handle.

One of the most recent methods of reducing the potential of the pipe below that of the rail has been suggested by Mr. Harold P. Brown, and has been very widely advertised by magazine articles and otherwise. This plan is to connect the negative lead of one generator to the pipe system in the station, and to run this generator at a greater difference of potential between its leads than between the negative bus bar. Mr. Brown, in a recent article in *Cassier's Magazine*, has claimed, by the use of this system, to have made a reduction in the output of the power station in Newark of 300 horse-power. It seems to me that this plan is radically at fault; for, even taking no account of the difficulties of running a special generator for this purpose, it is self-evident that all the current generated must be returned through the pipes, and, to my mind, it is absolutely wrong to compel a single ampère of current to enter the pipes; our efforts should rather be in the opposite direction. The complications necessary for using the double ground on our

machines, of giving up one machine for this special purpose, or even of installing a separate machine to do this work, will be apparent to every one.

A modification of this plan, however, and which, I believe, has never been publicly advocated, has occurred to me, namely, the application of what might be termed an inverted booster. Assuming that we have a separate set of pipe return feeders, and that in this feeder, before attaching it to the negative bus bar, we place a series dynamo which shall have a current capacity equal to the amount of current returned by the pipes, and a potential only sufficient to overcome the maximum difference of potential between the pipes and the track. This generator will have a tendency, then, to lower the potential of the pipes below that of the negative bus bar, and, being of very low potential, it need only be a very small machine. For instance, in the station above referred to, where the maximum current returned by the pipes was 50 ampères, the maximum difference of potential was also found to be less than 1 volt; if, therefore, we put in a generator of say 100 ampères capacity and 5 volts, we have a machine of only ½ kilowatt, which could readily be run by a 1 horse-power motor. You see how small a machine this plan demands. It would be automatic in its action, inexpensive and easily installed, and I believe would give absolute protection to the pipes. In cases such as those stated above, where the current returned by the pipes is abnormal, it would be necessary to put the rail-return system in proper shape, and then use the booster as a final refinement.

ELECTRICAL SECTION.

Stated Meeting, December 19, 1895.

MR. CARL HERING, President, in the chair.

MECHANICAL CONCEPTIONS OF ELECTRICAL PHENOMENA.

BY PROF. A. E. DOLBEAR,
Tuft's College, Massachusetts.

[*Concluded from vol. cxli, p. 463.*]

So far as we have knowledge to-day, the only factors we have to consider in explaining physical phenomena are: (1) Ordinary matter, such as constitutes the substance of the earth, and the heavenly bodies; (2) the ether, which is omnipresent; and (3) the various forms of motion, which are mutually transformable in matter, and some of which, but not all, are transformable into ether forms. For instance, the translatory motion of a mass of matter can be imparted to another mass by simple impact, but translatory motion cannot be imparted to the ether, and, for that reason, a body moving in it is not subject to friction, and continues to move on with velocity undiminished for an indefinite time; but the vibratory motion which constitutes heat is transformable into wave motion in the ether, and is transmitted away with the speed of light. The kind of motion which is thus transformed is not even a to-and-fro swing of an atom or molecule like the swing of a pendulum bob, but that due to a change of form of the atoms within the molecule, otherwise there could be no such thing as spectrum analysis. Vibratory motion of the matter becomes undulatory motion in the ether. The vibratory motion we call heat; the wave motion we call sometimes radiant energy, sometimes light. Neither of these terms is a good one, but we now have no others.

It is conceded that it is not proper to speak of the wave motion in the ether as *heat*; it is also admitted that the

ether is not heated by the presence of the wave—or, in other words, the temperature of the ether is absolute zero. Matter only can be heated. But the ether waves can heat other matter they may fall on, so there are three steps in the process and two transformations: (1) vibrating matter; (2) waves in the ether; (3) vibration in other matter. Energy has been transferred indirectly. What I want to impress in this is, that when a form of energy in matter is transformed in any manner so as to lose its characteristics, it is not proper to call it by the same name after as before, and this we do in all cases when the transformation is from one kind in matter to another kind in matter. Thus, when a bullet is shot against a target, before it strikes it has what we call mechanical energy, and we measure that in foot-pounds; after it has struck the target, the transformation is into heat, and this has its mechanical equivalent, but is not called mechanical energy, nor are the motions which embody it similar. The mechanical ideas in these phenomena are easy to grasp. They apply to the phenomena of the mechanics of large and small bodies, to sound, to heat and to light, as ordinarily considered, but they have not been applied to electric phenomena, as they evidently should be, unless it be held that such phenomena are not related to ordinary phenomena, as the latter are to one another.

When we would give a complete explanation of the phenomena exhibited by, say, a heated body, we need to inquire as to the antecedents of the manifestation, and also its consequents. Where and how did it get its heat? Where and how did it lose it? When we know every step of those processes, we know all there is to learn about them. Let us undertake the same thing for some electrical phenomena.

First, under what circumstances do electrical phenomena arise?

(1) *Mechanical*, as when two different kinds of matter are subject to friction.

(2) *Thermal*, as when two substances in molecular contact are heated at the junction.

(3) *Magnetic*, as when any conductor is in a changing magnetic field.

(4) *Chemical*, as when a metal is being dissolved in any solution.

(5) *Physiological*, as when a muscle contracts.

Each of these has several varieties, and changes may be rung on combinations of them, as when mechanical and magnetic conditions interact.

(1) In the first case, ordinary mechanical or translational energy is spent as friction, an amount measurable in foot-pounds, and the factors we know, a pressure into a distance. If the surfaces be of the same kind of molecules, the whole energy is spent as heat, and is presently radiated away. If the surfaces are of unlike molecules, the product is a compound one, part heat, part electrical. What we have turned in, we know to be a particular mode of motion. We have not changed the amount of matter involved; indeed, we assume, without specifying and without controversy, that matter is itself indestructible, and the product, whether it be of one kind or another, can only be some form of motion. Whether we can describe it or not is immaterial; but if we agree that heat is vibratory molecular motion, and there be any other kind of a product than heat, it, too, must also be some other form of motion. So, if one is to form a conception of the mechanical origin of electricity, this is the only one he can have—transformed motion.

(2) When heat is the antecedent of electricity, as in the thermo-pile, that which is turned into the pile we know to be molecular motion of a definite kind. That which comes out of it must be some equivalent motion, and if all that went into it were transformed, then all that came out would be transformed, call it by what name we will and let its amount be what it may.

(3) When a conductor is moved in a magnetic field, the energy spent is measurable in foot-pounds, as before, a pressure into a distance. The energy appears in a new form, but the quantity of matter being unchanged, the only changeable factor is the kind of motion, and that the motion is molecular is evident, for the molecules are heated. Mechanical or mass motion is the antecedent, molecular heat motion is the consequent, and the way we know there has been some

intermediate form is that heat is not conducted at the rate which is observed in such a case. Call it by what name one will, some form of motion has been intermediate between the antecedent and the consequent, else we have some other factor of energy to reckon with than ether, matter and motion.

(4) In a galvanic battery, the source of electricity is chemical action; but what is chemical action? Simply an exchange of the constituents of molecules, a change which involves exchange of energy. Molecules capable of doing chemical work are loaded with energy. The chemical products of battery action are molecules of different constitution, with smaller amounts of energy as measured in calories or heat units. If the results of the chemical reaction be prevented from escaping by confining them to the cell itself, the whole energy appears as heat and raises the temperature of the cell. If a so-called circuit be provided, the energy is distributed through it and less heat is spent in the cell; but whether it be in one place or another, the mass of matter involved is not changed, and the variable factor is the motion, the same as in the other cases. The mechanical conceptions appropriate are the transformation of one kind of motion into another kind by the mechanical conditions provided.

(5) Physiological antecedents of electricity are exemplified by the structure and mode of operation of certain muscles in the gymnotus and other electrical animals. The mechanical contraction of them results in an electrical excitation, and, if a proper circuit be provided, in an electric current. The energy of a muscle is derived from food, which is itself but a molecular compound loaded with energy of a kind available for muscular transformation. Bread and butter has more available energy, pound for pound, than has coal, and can be substituted for coal for running an engine. It is not used, because it costs so much more. There is nothing different, so far as the factors of energy go, between the food of an animal and the food of an engine. What becomes of the energy depends upon the kind of structure it acts on. It may be changed into translatory, and the whole

body moves in one direction; or into molecular, and then appears as heat or electrical energy.

If one confines his attention to the only variable factor in the energy in all these cases, and traces out in each just what happens, he will have only motions of one sort or another, at one rate or another, and there is nothing mysterious which enters into the processes.

We will turn now to how electricity manifests itself, and what it can do. It may be well to point out at the outset what has occasionally been stated, but which, in my judgment, has not received the philosophical attention it deserves, namely, that electrical phenomena are reversible, that is, any kind of a physical process which is capable of producing electricity, electricity is itself able to produce. Thus, to name a few: If mechanical motion develops electricity, electricity will produce mechanical motion; the movement of a pith ball is a simple case. If chemical action can produce it, it will produce chemical action, as in the decomposition of water and electroplating. As heat may be its antecedent, so will it produce heat. If magnetism be an antecedent factor, magnetism may be its product. What is called induction may give rise to it in an adjacent conductor, and, likewise, induction may be its effect.

Let us suppose ourselves to be in a building in which a steam engine is at work. There is fuel, the furnace, the boiler, the pipes, the engine with its fly-wheel turning. The fuel burns in the furnace, the water is superheated in the boiler, the steam is directed by the pipes, the piston is moved by the steam pressure, and the fly-wheel rotates because of proper mechanism between it and the piston. No one who has given attention to the successive steps in the process is so puzzled as to feel the need of inventing a particular force, or a new kind of matter, or any agency, at any stage of the process, different from the simple mechanical ones represented by a push or a pull. Even if he cannot see clearly how heat can produce a push, he does not venture to assume a genii to do the work, but for the time is content with saying that if he starts with motion in the

furnace and stops with the motion of the fly-wheel, any assumption of any other factor than some form of motion between the two would be gratuitous. He can truthfully say that he understands the *nature* of that which goes between the furnace and the wheel; that it is some sort of motion, the particular kinds of which he might make out at his leisure.

Suppose once more that, across the highway from this engine house, there is another building, where all sorts of machines—lathes, planers, drills, etc.—are running, but that the source of the power for all this is out of sight, and that one can see no connection between this and the engine on the other side of the street. Would one need to suppose there was anything mysterious between the two—a force, a fluid, an immaterial something? I am asking the question on the supposition that one was not aware of the shaft that might be between the two buildings, and that it was not obvious on simple inspection how the machines got their motions from the engine. I think no one would be puzzled because he did not know just what the intervening mechanism might be. If the boiler were in the one building, and the engine in the other with the machines, he could see nothing moving between them, even if the steam pipes were of glass. If matter of any kind were moving, he could not see it there. He would say there *must* be something moving, or pressure could not be transferred from the one place to the other.

Substitute for the furnace and boiler a galvanic battery or a dynamo; for the machines of the shop, one or more motors with suitable wire connections. When the dynamo goes the motors go; when the dynamo stops the motors stop; nothing can be seen to be turning or moving in any way between them. Is there any necessity for assuming a mysterious agency, or a force of a *nature* different from the visible ones at the two ends of the line? Is it not certain that the question is, how does the motion get from the one to the other, whether there be a wire or not? If there be a wire, it is plain that there is motion in it, for it is heated its whole length, and heat is known to be a mode of motion,

and every molecule which is thus heated must have had some antecedent motions. Whether it be defined or not, and whether it be called by one name or another, are quite immaterial if one is concerned only with the *nature* of the action, whether it be matter or ether, or motion or abracadabra.

Once more: suppose we have a series of active machines. An arc lamp, radiating light waves, gets its energy from the wire which is heated, which in turn gets its energy from the electric current, that from a dynamo, the dynamo from a steam engine, that from a furnace and the chemical actions going on in it. Let us call the chemical actions *A*, the furnace *B*, the engine *C*, the dynamo *D*, the electric lamp *E*, the ether waves *F*. (*Fig. 4.*)

The product of the chemical action is molecular motion, called heat in the furnace. The product of the heat is mechanical motion in the engine. The product of the me-

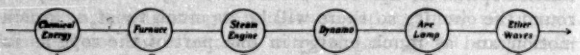

FIG. 4.

chanical motion is electricity in the dynamo. The product of the electrical current in the lamp is light waves in the ether. Nobody hesitates an instant to speak of light waves as forms of motion, for they are described as undulations in the ether at right angles to the direction of the radiation. No one hesitates for an instant to speak of the heat as being molecular motion, nor of the motions of the engine as being mechanical; but when we come to the product of the dynamo, which we call electricity, behold, nearly every one says, not that he does not know what it is, but that no one knows! Does any one venture to say he doesn't know what heat is, because he cannot describe in detail just what goes on in a heated body as it might be described by one who saw with a microscope the movements of the molecules? Let us go back for a moment to the proposition stated early in the address, namely, that if any body of any magnitude moves, it is because some other body in motion and in contact with it

has imparted its motion by mechanical pressure. Therefore, the ether waves at *F* imply continuous motions of some sort from *A* to *F*. That they are all motions of ordinary matter from *A* to *E* is obvious, because continuous matter is essential for the maintenance of the actions. At *E* the motions are handed over to the ether, and they are radiated away as light waves.

A puzzling electrical phenomenon has been what has been called its duality—states which are spoken of as positive and negative. Thus, we speak of the positive plate of a battery and the negative pole of a dynamo, and another troublesome condition to idealize has been, how it could be that, in an electric circuit, there could be as much energy at the most remote part as at the source. But, if one will take a limp rope, 8 or 10 feet long, tie its ends together, and then begin to twist it at any point, he will see the twist move in a right-handed spiral on the one hand, and in a left-handed spiral on the other, and each may be traced quite round the circuit; so there will be as much twist, as much motion, and as much energy in one part of the rope as in any other; and if one chooses to call the right-handed twist positive, and the left-handed twist negative, he will have the mechanical phenomenon of energy distribution and the terminology analogous to what they are in an electric circuit. So far, there is no trouble; but one can see the rope as a whole twisting, and nothing can be seen in an electric conductor. Are not the cases more dissimilar than the mechanical analogy would make them seem to be?

Are there any phenomena which imply that rotation is going on in an electrical conductor? There are. An electric arc, which is a current in the air, and is, therefore, less constrained than it is in a conductor, rotates. Especially marked is this when in front of the pole of a magnet; but the rotation may be noticed in an ordinary arc by looking at it with a stroboscopic disk, rotated so as to make the light to the eye intermittent at the rate of four or five hundred per second. A ray of plane polarized light, parallel with a wire conveying a current, has its plane of vibration twisted to the right or left, as the current goes one way or the other

through the wire, and to a degree that depends upon the distance it travels; not only that, but if the ray be sent, by reflection, back through the same field, it is twisted as much more—a phenomenon which convinces one that rotation is going on in the space through which the ray travels. If the ether through which the ray be sent were simply warped or in some static stress, the ray, after reflection, would be brought back to its original plane, which is not the case. This rotation in the ether is produced by what is going on in the wire. The ether waves called light are interpreted to imply that molecules originate them by their vibrations, and that there are as many ether waves per second as of molecular vibrations per second. In like manner, the implication is the same, that if there be rotations in the ether they must be produced by molecular rotation, and there must be as many rotations per second in the ether as there are molecular rotations that produce them. The space about a wire carrying a current is often pictured as filled with whorls indicating this motion, and one must picture to himself, not the wire as a whole rotating, but each individual molecule independently. But one is aware that the molecules of a conductor are practically in contact with each other, and that if one for any reason rotates, the next one to it would, from frictional action, cause the one it touched to rotate in the opposite direction, whereas, the evidence goes to show that all rotation is in the same direction.

How can this be explained mechanically? Recall the kind of action that constitutes heat, that it is not translatory action in any degree, but vibratory, in the sense of a change of form of an elastic body, and this, too, of the atoms that make up the molecules of whatever sort. Each atom is so far independent of every other atom in the molecule that it can vibrate in this way, else it could not be heated. The greater the amplitude of vibration, the more free space to move in, and continuous contact of atoms is incompatible with the mechanics of heat. There must, therefore, be impact and freedom alternating with each other in all degrees in a heated body. If, in any way, the atoms themselves *were* made to rotate, their heat impacts not only would restrain

the rotations, but the energy also of the rotation motion would increase the vibrations; that is, the heat would be correspondingly increased, which is what happens always when an electric current is in a conductor. It appears that the colder a body is the less electric resistance it has, and the indications are that at absolute zero there is no resistance; that is, impacts do not retard rotation, but it is also apparent that any current sent through a conductor at that temperature would at once heat it. This is the same as saying that an electric current could not be sent through a conductor at absolute zero.

So far, mechanical conceptions are in accordance with electrical phenomena, but there are several others yet to be noted. I have spoken of electrical phenomena as molecular or atomic phenomena, and there is one more in that category which is well enough known, and which is so important and suggestive, that I wonder its significance has not been seen by those who have sought to interpret electrical phenomena. I refer to the fact that electricity cannot be transmitted through a vacuum. An electric arc begins to spread out as the density of the air decreases, and presently it is extinguished. An induction spark that will jump 2 or 3 feet in air cannot be made to bridge the tenth of an inch in an ordinary vacuum. A vacuum is a perfect non-conductor of electricity. Is there more than one possible interpretation to this, namely, that electricity is fundamentally a molecular and atomic phenomenon, and in the absence of molecules cannot exist? One may say: "Electrical *action* is not hindered by a vacuum," which is true, but has quite another interpretation than the implication that electricity is an ether phenomenon. The heat of the sun in some way gets to the earth, but what takes place in the ether is not heat conduction. There is no heat in space, and no one is at liberty to say, or to think, that there can be heat in the absence of matter.

When heat has been transformed into ether waves it is no longer heat, call it by what name one will. Formerly such waves were called heat waves; no one, properly informed, does that now. In like manner, if electrical motions

or conditions in matter be transformed, no matter how, it is no longer proper to speak of such transformed motions or conditions as electricity. Thus, if electrical energy be transformed into heat, no one thinks of speaking of the latter as electrical. If the electrical energy be transformed into mechanical of any sort, no one thinks of calling the latter electrical because of its antecedent. If electrical motions be transformed into ether actions of any kind, why should we continue to speak of the transformed motions or energy as being electrical? Electricity may be the antecedent, in the same sense as mechanical motion of a bullet may be the antecedent of the heat developed when the latter strikes the target; and if it be granted that a vacuum is a perfect non-conductor of electricity, then it is manifestly improper to speak of any phenomenon in the ether as an electrical phenomenon. It is from the failure to make this distinction that most of the trouble has come in thinking on this subject. Some have given all their attention to what goes on in matter, and have called that electricity; others have given their attention to what goes on in the ether, and have called that electricity, and some have considered both as being the same thing, and have been confounded.

Let us consider what is the relation between an electrified body and the ether about it.

When a body is electrified, the latter at the same time creates an ether stress about it, which is called an electric field. The ether stress may be considered as a warp in the distribution of the energy about the body, by the new positions given to the molecules by the process of electrification. I have already said that the evidence from other sources is that atoms, rather than molecules, in larger masses, are what affect the ether. One needs to inquire for what knowledge we have as to the constitution of matter or of atoms. There is only one hypothesis to-day that has any degree of probability; that is the vortex-ring theory, which describes an atom as being a vortex ring of ether, in the ether. It possesses a definite amount of energy in vir-

tue of the motion which constitutes it, and this motion differentiates it from the surrounding ether, giving it dimensions, elasticity, momentum, and the possibility of translatory, rotary, vibratory motions and combinations of them. Without going further into this, it is sufficient, for a mechanical conception, that one should have so much in mind, as it will vastly help in forming a mechanical conception of reactions between atoms and the ether. An exchange of energy between such an atom and the ether is not an exchange between different kinds of things, but between different conditions of the same thing. Next, it should be remembered that all the elements are magnetic in some degree. This means that they are themselves magnets, and every magnet has a magnetic field unlimited in extent, which can almost be regarded as a part of itself. If a magnet of any size be moved, its field is moved with it, and if in any way the magnetism be increased or diminished, the field changes correspondingly.

Assume a straight bar electro-magnet in circuit, so that a current can be made intermittent, say, once a second. When the circuit is closed and the magnet is made, the field at once is formed and travels outwards at the rate of 186,000 miles per second. When the current stops, the field adjacent is destroyed. Another closure develops the field again, which, like the other, travels outwards; and so there may be formed a series of waves in the ether, each 186,000 miles long, with an electro-magnetic antecedent. If the circuit were closed ten times a second, the waves would be 18,600 miles long; if 186,000 times a second, they would be but 1 mile long. If 400 million of millions times a second, they would be but the forty-thousandth of an inch long, and would then affect the eye, and we should call them light waves, but the latter would not differ from the first wave in any particular except in length. As it is proved that such electro-magnetic waves have all the characteristics of light, it follows that they must originate with electro-magnetic action, that is, in the changing magnetism of a magnetic body. This makes it needful to assume that the atoms which originate waves are magnets, as they are

experimentally found to be. But how can a magnet, not subject to a varying current, change its magnetic field? The strength or density of a magnetic field depends upon the form of the magnet. When the poles are near together, the field is densest; when the magnet is bent back to a straight bar, the field is rarest or weakest, and a change in the form of the magnet from a U-form to a straight bar would result in a change of the magnetic field within its greatest limits. A few turns of wire wound about the poles of an ordinary U-magnet, and connected to an ordinary magnetic telephone, will enable one, listening to the latter, to hear the pitch of the former loudly reproduced when the magnet is struck like a tuning-fork so as to vibrate. This shows that the field of the magnet changes at the same rate as the vibrations.

Assume that the magnet becomes smaller and smaller until it is of the dimensions of an atom, say, for an approximation, the fifty-millionth of an inch. It would still have its field; it would still be elastic and capable of vibration, but at an enormously rapid rate; but its vibration would change its field in the same way, and so there would be formed those waves in the ether, which, because they are so short that they can affect the eye, we call light. The mechanical conceptions are legitimate, because based upon experiments having ranges through nearly the whole gamut as waves in ether.

The idea implies that every atom has what may be loosely called an electro-magnetic grip upon the whole of the ether, and any change in the former brings some change in the latter.

Lastly, the phenomenon called induction may be mechanically conceived.

It is well known that a current in a conductor makes a magnet of the wire, and gives it an electro-magnetic field, so that other magnets in its neighborhood are twisted in a way tending to set them at right angles to the wire. Also, if another wire be adjacent to the first, an electric current having an opposite direction is induced in it. Thus:

Consider a permanent magnet *A* (*Fig. 5*), free to turn on

an axis in the direction of the arrow. If there be other free magnets, *B* and *C*, in line, they will assume such positions that their similar poles all point one way. Let *A* be twisted to a position at right angles, then *B* will turn, but in the opposite direction, and *C* likewise. That is, if *A* turn in the direction of the hands of a clock, *B* and *C* will turn in the opposite direction. These are simply the observed movements of large magnets. Imagine that these magnets be reduced to atomic dimensions, yet retaining their magnetic qualities, poles and fields. Would they not evidently move in the same way and for the same reasons? If it be true that a magnet field always so acts upon another as to tend by rotation to set the latter into a certain position with reference to the stress in that field, then, *wherever there is a changing magnetic field, there the atoms are being adjusted by it.*

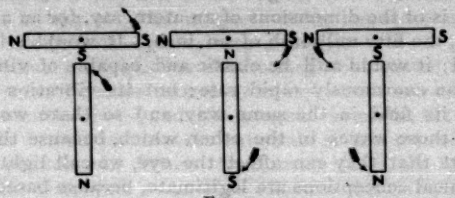

FIG. 5.

Suppose we have a line of magnetic needles free to turn, hundreds or thousands of them, but disarranged. Let a strong magnetic field be produced at one end of the line. The field would be strongest and best conducted along the magnet line, but every magnet in the line would be compelled to rotate, and if the first were kept rotating the rotation would be kept up along the whole line. This would be a mechanical illustration of how an electric current travels in a conductor. The rotations are of the atomic sort, and are at right angles to the direction of the conductor.

That which makes the magnets move is inductive magnetic ether stress, but the advancing motion represents mechanical energy of rotation, and it is this motion with the resulting friction which causes the heat in a conductor.

What I would like to emphasize is, that the action in the ether is not electric action, but more properly the result of electro-magnetic action. Whatever name be given to it, and however it comes about, there is no good reason for calling any kind of an ether action electrical.

Electric action, like magnetic action, begins and ends in matter. It is subject to transformations into thermal and mechanical actions, also into ether stress—right-handed or left-handed—which, in turn, can similarly affect other matter, but with opposite polarities.

In his "Modern Views of Electricity," Prof. O. J. Lodge warns us, in a way I quite approve, that perhaps, after all, there is no such *thing* as electricity—that electrification and electric energy may be terms to be kept: but if electricity as a term be held to imply a force, a fluid, an imponderable, or a thing which could be described by some one who knew enough, then it has no degree of probability, for spinning atomic magnets seem capable of developing all the electrical phenomena we meet.

NOTES AND COMMENTS.*

DUCTILE CAST IRON.

We learn from the *Iron Age* that the East Chicago Foundry Company, whose works are at East Chicago, Ind., are placing a new product on the market, which they term "ductile cast iron." Their experiments, which have extended over the past year and a half, have been so satisfactory that they have decided to abandon their former business of making general iron castings, and have fitted up their foundry to make ductile iron castings exclusively. They are prepared to make castings of this character ranging from 10 pounds to 10,000 pounds in weight, which are not only solid, homogeneous and free from blow-holes, but which also may be drawn under the hammer or perfectly welded, and will work well under the planer or other tools.

The samples shown by the company are of an extraordinary character, suggesting many of the qualities of steel, but at the same time presenting features peculiar to iron. The metal is remarkable for its strength coupled with its ductility. A test bar, cast with the breaking section curved in on both sides, instead of being cut out afterwards as usual, was tested by Fraser &

* From the Secretary's monthly reports.

Chalmers, and showed a tensile strength of 63,000 pounds to the square inch. Other tests have shown over 80,000 pounds. After being heated to a dull red and plunged into cold water, it can be cut easily with a file, showing that it takes no temper. Specimens of castings are shown which have had portions heated and drawn out flat under the hammer, afterward being twisted cold and pounded flat, without a sign of fracture. Gates from castings are shown which have stood remarkable torture of this character. A notable piece of work is a heavy chain, of which the links were cast open, then joined and the open spaces welded without the use of flux. Valve stems, crank shafts and other similar pieces are shown which have been finished to pattern in a lathe, exhibiting a smooth surface without a suspicion of a blow-hole. Intricate castings are exhibited which have been reproduced regularly without a failure, while a very high percentage of losses has been reported when made by other methods of producing very strong castings.

It is the intention of the company to meet the demand for castings of the highest grade, competing with drop forgings and aiming to produce shapes which are difficult to work under a hammer, but for which castings have heretofore not been found sufficiently strong and trustworthy. It has been shown by extensive experiments that the castings made by this company are well adapted for electrical apparatus, owing to their high conductivity. Another important field has thus been opened which is full of possibilities.

THE PASSING OF WELSH SUPREMACY.

We quote the following from the editorial comments of the *Iron Age* on the apparent collapse of the tin-plate industry of Wales:

* * * In the collapse of the Welsh tin-plate trade we have an illustration of a business calamity on a tremendous scale. Possibly in the history of the world a parallel case cannot be found, in which, without the intervention of war or religious or political persecution, a flourishing industry of such vast dimensions has been sapped and almost destroyed in less than a decade The accounts which are now being published about the hard times in Wales, the stoppage of works, the ruin of once opulent manufacturers, the savage reductions in wages, and the despair of those who can see no market for their products, are distressing in the extreme.

The assumption appears safe that even the most enthusiastic advocate of an American tin plate industry did not dream that within the short space of six years from the establishment of tin-plate factories on this side of the Atlantic the Welsh tin plate trade would be in a state of decay. The Welsh manufacturers were known to be sturdy fighters; their business had been established for 150 years, during which time they had monopolized the tin-plate business of the world; they were believed to be in possession of resources in cheap material and an abundance of cheap labor, whose real power had never been seriously tested, and they had surrounded their business with a veil of mystery and fortified it by such a formidable barrier of awe-inspiring trade terms that little wonder exists that many Americans

doubted the wisdom of the attempt to set up an opposition industry here. In fact, the greatest doubters were among those who were most intimately acquainted with Welsh tin-plate manufacturers and their methods. So short a time has elapsed since American tin-plates began to be an article of commerce, that it is easy to remember how confident were the Welsh makers that the business would never be established here, and how valiantly they talked of the day when American tin-plate factories would be roofless and their amateur workmen scattered to pursue other occupations. They would not believe some of their most wide-awake colleagues who visited this country in 1891 and 1892 and carried back "scare" reports of what they had seen. Even so late as last summer, when the price of steel rose here, they dreamed dreams and saw visions in which they were again reveling in the undisputed occupancy of American markets. But with the fall in steel their visions faded and, perhaps, they then for the last time permitted themselves to hope of regaining their standing in this country. That hope has been succeeded by blank despair, as purchasers of Welsh tin-plates on American account are now seen to fall off rapidly from month to month, while American tin-plate works are being enlarged and their number increased. * * *

THE COMMERCIAL VALUE OF APPLIED CHEMISTRY.

Professor Dewar's recent lecture at the Royal Institution was a rapid survey of the galloping pace at which chemical discovery of value in the arts has lately proceeded, says the London *Chronicle*. It was a complete justification of Mr. Ludwig Mond's dictum that chemical research spells commercial success.

Take, for instance, what Mr. Mond himself has brought to light and utilized, all through his attempts to improve the gas battery first invented by Lord Justice Grove. Why cannot we turn coal directly into electricity without the cumbrous boiler, steam engine and dynamo process intervening—burn it up as you burn up zinc in a galvanic battery? Well, the idea is very magnificent, but not yet within the range of practical science.

But the suggestion that carbonic oxide might be used in some way led Mr. Mond to discover a strange and totally unexpected property of this gas, namely, that it will directly unite with metallic iron and nickel to form gases which are called carbonyls of these metals. Could anything be more strange than the idea of iron as gas at an ordinary temperature? And could anything be more valuable? For as soon as you heat these carbonyls they give out the metal again with the greatest facility. The result is, that Mr. Mond is now using carbonic oxide to extract nickel from its ores. He gets nickel carbonyl as a gas, subsequently heats it to make it part with its nickel, and sends back the carbonic oxide to extract some more. In this way pure nickel can be obtained, for the gas will only pick up the nickel.

Professor Dewar also described the famous Castner process for getting pure soda from common salt. Here we have electrolysis at work once more, but with a movable electrode in the shape of a flowing stream of mercury,

which bears away the metallic sodium in amalgamic solution as fast as it is separated from the salt. The amalgam then passes into water, where the sodium dissolves as hydrate, leaving the mercury free to go round again.

But there is something more than this. As the sodium dissolves it generates electricity. Formerly this electricity was generated in the electrolytic bath itself, and obstructed the operating current by setting up a "back current" on its own account. Now, the "back current" being separately generated, is made to travel the right way, and supplement instead of obstructing the working current.

Finally, Professor Dewar illustrated the discovery of the effect of the oxides of the rare earths, such as those of zirconium, thorium and lanthanum, in transforming heat into light. This is the principle of the incandescent gas burners. The now familiar mantle, which is suspended in an atmospheric or Bunsen burner, and glows so brilliantly, is made (as Professor Dewar showed) by saturating a cotton mantle with salts of these metals and then incinerating it. The organic cotton is all burned away, leaving nothing but a skeleton mantle of oxides and silica. When these are suspended in the colorless gas flame they glow in the brilliant fashion now so familiar, far surpassing the incandescence which can be obtained from platinum, magnesium, lime and other substances heated to the same point.

FORMATION OF CYANOGEN FROM AMMONIA.

The occurrence of cyanide of potassium in blast-furnaces was first, in 1837, observed by Thomas Clark, on the Clyde. The crusts and efflorescences forming about the tuyeres, especially after scouring, consisted of nearly equal parts of cyanide and of potash. The observation was soon confirmed from other parts, but no adequate explanation of the occurrence has been given. The investigation which Dr. E. Bergmann has started, in conjunction with Dr. Bueb, on the instigation of Professor Bunte, does not settle the question whether or not the cyanogen in such cases is really derived from the free nitrogen of the atmosphere; but the experiments have a high practical interest. Dr. Bueb has not yet published his researches; Dr. Bergmann gives a detailed account of his share of the work in *Schilling's Journal für Gasbeleuchtung*. The study concerns the action of ammonia, diluted or not with illuminating gas or Dowson gas, on glowing charcoal. From a reservoir, provided with a gas meter, the gas passed through the bottle in which the ammonia was generated. The dried gases then entered a porcelain tube, filled with charcoal, which was heated up to 1,180° C. in a Fletcher gas stove; an aspirator was joined to the other end. The temperature was ascertained by means of Princeps' alloys. At 800° only 4 per cent. of the nitrogen supplied as ammonia was converted into cyanogen; at 1,000° 24 per cent. When illuminating gas was admixed, 60 per cent. could be gained at the highest temperature applied, 1,180°. Of the remaining 40 per cent. of the ammonia, 20 per cent. was recovered as ammonia, and 20 per cent. decomposed into nitrogen and hydrogen. The coal gas acts either simply as a diluent—and

the experiments prove that a concentrated current of ammonia is not profitable—or it may be decomposed according to the formula $C_2 + 2NH_3 = 2CNH + 2H_2$. If the latter be the case, gas containing higher hydrocarbons should prove more effective; the addition of penthane was found useless, however, if not deleterious. There is a third possibility, $CO + NH_3 = CNH + H_2O$. This reaction would be important for Dowson gas. When working simply according to this formula, that is, without using charcoal, a little cyanogen was, indeed, formed, but the quantity was very slight. The experiments were made with about 6 grams of ammonia, 40 or 50 liters of the other gases, and lasted from one to three hours. The following is a summary of the results: Hydrocyanic acid, and not cyanide of ammonia, is formed when ammonia is passed over glowing charcoal; by-products are nitrogen and hydrogen, never methane. The addition of coal gas increases the yield of cyanogen, and keeps down the splitting up of ammonia into its constituents. Hydrocarbons of higher molecular weight seem to prevent the decomposition of the ammonia, becoming themselves decomposed, and their admixture is hence not advisable. Carbonic oxide behaves like coal gas, but it favors the splitting up of ammonia; the same applies to Dowson gas. These gases act as diluents; the diluted ammonia is not so easily split up as the concentrated ammonia. The current should not be too rapid. The temperature depends upon the nature of the gases added; on the whole, a temperature of 1,100° gives the best results. A certain percentage of ammonia always escapes unattacked. This percentage increases in the presence of hydrocarbons of higher molecular weight. Dr. Bergmann does not discuss the practical bearing of these researches.—*Engineering.*

THE MANUFACTURE OF ARTIFICIAL SILK.

London *Nature* has the following interesting item apropos to the impending introduction into England of the manufacture of artificial silk from cellulose by the process devised by M. de Chardonnet, which was described in the *Journal* several years ago, viz:

"Lancashire is on the eve of some important expansions of the textile trades, for, from an interesting article in the *Times*, it appears that the manufacture of artificial silk from wood pulp will shortly be added to her industries.

"At present the wood-silk comes from France, large works having been established at Besançon under patents granted to Count Hilaire de Chardonnet, who discovered the process, and first established in 1893 the fact that it might be made commercially successful. The demand for the new commodity increased so considerably that the idea of introducing its manufacture into England was mooted, with the result that a number of silk and cotton manufacturers met to discuss the question, and finally sent out to Besançon a deputation, consisting of some of their own number, an engineer, a chemist, and a lawyer, to investigate the subject thoroughly. This was done, and the outlook was found to be so promising that certain concessions have been

secured and a company is now in process of formation, and, to begin with, a factory, which will cost £30,000, is to be built near to Manchester for the manufacture of artificial silk yarn from wood pulp, for sale to weavers, who will work it up by means of their existing machinery.

"The way in which wood pulp can be converted into silk yarn is explained in the *Times*. The pulp, thoroughly cleansed, and looking very much like thick gum, is put in cylinders, from which it is forced by pneumatic pressure into pipes passing into the spinning department. Here the machinery looks like that employed in Lancashire spinning sheds, except that one of the pipes referred to runs along each set of machines. These pipes are supplied with small taps, fixed close together, and each tap has a glass tube, about the size of a gas burner, at the extreme point of which is a minute aperture through which the filaments pass. These glass tubes are known as 'glass silkworms,' and some 12,000 of them are in use in the factory at Besançon. The effect of the pneumatic pressure in the cylinders referred to above is to force the liquid matter not only along the iron tubes, but also, when the small taps are turned on, through each of the glass silkworms. It appears there is a scarcely perceptible globule. This a girl touches with her thumb, to which it adheres, and she draws out an almost invisible filament, which she passes through the guides and on to the bobbin. Then, one by one, she takes eight, ten or twelve other such filaments, according to the thickness of the thread to be made, and passes them through the same guides and on to the same bobbin. This done, she presses them together with her thumb and forefinger, at a certain point between the glass silkworms and the guides. Not only do they adhere, but thenceforward the filaments will continue to meet and adhere at that point, however long the machinery may be kept running. In this way the whole frame will soon be set at work, the threads not breaking until the bobbin is full, when they break automatically, while they are all of a uniform thickness. The new product is said to take dye much more readily than the natural silk. The chief difference in appearance between the natural and the artificial silk is in the greater luster of the latter. The success already secured by the new process in France is such that the introduction of the industry into Lancashire is expected to produce something like revolution in the conditions of trade there, not only by bringing into existence a new occupation, but also by finding more work for a good deal of the weaving machinery that is now only partially employed."

THE INVISIBLE SPECTRUM.

The statement is interesting as coming from Prof. William Huggins, foremost in such researches, that beyond the violet end of the spectrum there is a whole gamut of invisible rays which only reveal themselves by their effect in promoting chemical action, and similarly, beyond the other end of the visible scale, the deep red, there is a gamut of invisible or dark rays which are only perceived by their heating effects. Some idea, he says, of the importance of the "ultra red" may be gathered from the fact that it has been traced to a dis-

tance nearly ten times as long as the whole range of the visible or light-giving region of the spectrum; to learn, then, the character of these mysterious dark rays, it has been clearly necessary for science to fit itself with some new sort of eyes for seeing what ordinary eyes cannot, namely, heat rays and chemical rays, and, in respect of the latter, the photographic plate has brought out some wonderful facts, while the bolometer has been used in feeling for absorption lines in the great invisible spectrum which lies beyond the red.

TECHNICAL NOTES.

For Plating Aluminum with Copper, Margot prepares the aluminum surface by immersion in a bath of an alkaline carbonate (caustic alkali should answer better.—ED.), then a thorough rinsing in clear water, followed by a dip in a 5 per cent. solution of hydrochloric acid and subsequent rinsing. The article is now immersed in a weak and slightly acid solution of copper sulphate, which causes a thin but adherent coating of copper. The article is then removed to the electrolytic bath, in which the coating may be made as heavy as desired.

For Etching Letters, Names or Designs on metallic goods, such as knives, for instance, the *Zeit. f. Electrochem.* gives the following directions: The objects are covered with the following mixture: 1 liter of naphtha, ½ kilogram of carbon bisulphide, 2 kilograms of pulverized resin, and 1·5 kilograms of chloride of copper. After covering with a thin layer of this, the stencil or type is washed with a weak solution of potash and pressed on the surface, which is then washed, after which it is wet with a weak solution of sal-ammoniac, through which a current is passed, which then etches the metal where the insulating coat has been removed.

A Pavement used in Vienna consists of granulated cork mixed with mineral asphalt and other cohesive substances, compressed into blocks of suitable size and form. Among the numerous advantages set forth in its behalf are cleanliness, noiselessness, durability, elasticity, freedom from slipperiness, whether wet or dry, and moderate cost. Unlike wood, it is non-absorbent, and, consequently, inodorous. It presents the minimum resistance to traction, and, being elastic under passing loads, does away with the vibration caused by heavy teaming. The blocks are embedded in tar, and rest upon a concrete base 6 inches thick. When taken up for examination they have exhibited, when compared with new ones, a reduced thickness by wear of less than ½ inch—this in the case of a section of a London street leading to the Great Eastern Railway station, subjected to continuous heavy traffic, the blocks having been in use nearly two years.

Electricity Direct from Coal.—Two processes have recently been described by which electricity can be produced direct from combustion of coal. One is that of Dr. W. W. Jacques, and consists in blowing air through a bath

of fused caustic soda, with a carbon anode and iron cathode, whereby he obtains a very large current, but the voltage is low.

Dr. Alfred Coehn, of Germany, takes as a basis for his work the principle that a method for obtaining electrical energy direct from the oxidation of carbon may reasonably be sought, first, by determining the conditions under which carbon can be attacked in an electrolyte by the aid of an external circuit, and thereby adapting these conditions for the production of a current.

By experiment, Dr. Coehn has reached the following conclusions:

(1) It is possible to prepare a solution of carbon by electrolytic means.

(2) Carbon can be separated from such a solution at the cathode.

(3) A cell may be made having carbon for its soluble electrode.

Neither of these authors has made the details of his method sufficiently clear to permit of an intelligent criticism.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, June 17, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 17, 1896.

JOS. M. WILSON, President, in the chair.

Present, 225 members and visitors.

Additions to membership since last report, 8.

The Secretary reported two vacancies in the Committee on Science and the Arts, caused by the resignations, respectively, of Mr. D. E. Crosby and Mr. Henry Brinton. An election to fill the vacancies resulted in the choice of Mr. Clayton W. Pike for the unexpired term of Mr. Crosby, and Mr. Louis E. Levy for the unexpired term of Mr. Brinton.

Mr. Chas. A. Hexamer, Secretary of the Philadelphia Board of Fire Underwriters, read a paper descriptive of a series of tests of the "Fire-retarding Qualities of Wire Glass," recently made under his directions. (The paper will appear in the *Journal*.)

Mr. W. N. Jennings exhibited and commented upon a series of lantern views from his own photographs, showing the destructive effects of the tornado which lately devastated the city of St. Louis, Mo., and its vicinity.

Prof. F. L. Garrison supplemented the previous speaker's comments with some additional views and remarks on the general subject. The subject was further discussed by Messrs. Chas. James and Jacob Reese.

Prof. Angelo Heilprin exhibited and described an improved window of his invention, designed especially for service as a railway-car window.

The Secretary's report followed, of which an abstract appears in this impression of the *Journal*.

Adjourned.

WM. H. WAHL, *Secretary*.